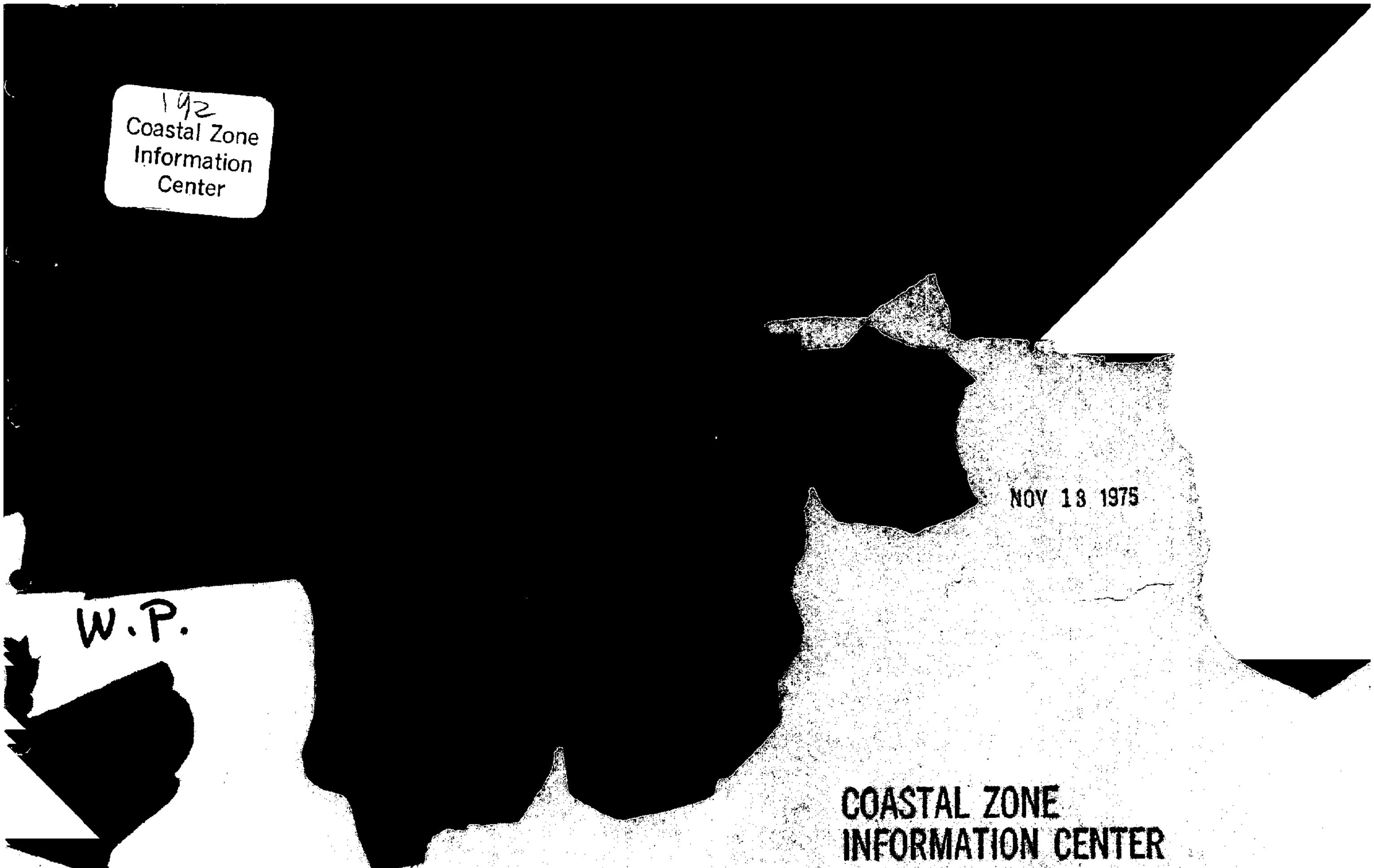

W.P.

Recreational Boating Impact on Chesapeake and Chincoteague Bays

part 1:
Boating Capacity Planning System

prepared for the:
Coastal Zone Management Program
Department of Natural Resources
State of Maryland

by:
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Maryland. Dept. of Natural Resources

draft December, 1974

RECREATIONAL BOATING IMPACTS: CHESAPEAKE AND CHINCOTEAGUE BAYS

PART 1: BOATING CAPACITY PLANNING SYSTEM

PREPARED FOR THE

COASTAL ZONE MANAGEMENT PROGRAM
WATER RESOURCES ADMINISTRATION

STATE OF MARYLAND

DEPARTMENT OF NATURAL RESOURCES

BY

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FOREWORD

Recreational Boating Impacts: Chesapeake and Chincoteague Bays is a two part report of a study of recreational boating congestion, environmental effects, activity regulation, and facility planning in the tidal waters of Maryland's two great bays.

The study was initiated in May, 1974 and is scheduled for completion in November, 1975. Part One of this report presents the findings of the study's first phase, in which existing boating and environmental conditions and the literature on recreational boating operational requirements, environmental effects, and carrying capacity are reviewed, and a boating capacity planning system is recommended.

Part Two will present the study's second phase findings on conditions in sub-areas of the Bays, apply the boating capacity planning system to the sub-areas and their subsidiary management units, provide guidelines for boating facility site planning and design, and recommend management measures for optimization of recreational boating need satisfaction and avoidance of environmental disturbances.

The study was performed by Roy Mann Associates, Inc. under contract to the Maryland Department of Natural Resources Water Resources Administration, Coastal Zone Management Program. Partial funding for the project was provided by the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration.

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SUMMARY

Recreational Boating Impacts / Chesapeake and Chincoteague Bays, Part I: Boating Capacity Planning System deals with the dual problems of boating congestion and environmental effects resulting from recreational boating activity and facility construction in Maryland tidal waters.

This study has not undertaken original research and has reviewed the literature to determine the state-of-the-art in knowledge of boating effects on the environment, effects of facility construction, and environmental and recreational carrying capacities. Effects on the estuarine environment identified in the literature are summarized and displayed in chart and check-list format. Reports by contributors on special aspects of the aquatic and terrestrial ecosystems of the Bays, relative to recreational boating are appended to the study report. An annotated bibliography is included.

The study finds, from the reviewed literature, that environmental effects of recreational boating activity may reach significant levels, generally, in local aquatic and shoreline areas, particularly where tidal flushing and circulation are low, depth is shallow, and vulnerable biological and physical resources are within impact proximity. Such causative factors as engine exhausts, unconsumed or spilled fuel and oil, and toxic metals leached from anti-fouling compounds are among factors identified as affecting biological resources. Boating wake may exacerbate shoreline erosion where it exceeds normal or average wave height. Prop wash may cause significant local resuspension of sediments in shallow areas. Coliform counts in the vicinity of marinas on

high-activity weekends have been found to be higher than on normal periods, although insufficient research has been undertaken to isolate waste effects deriving from boating facilities from those deriving from other contributors.

The effects of marina construction on shoreline environments are better known; displacement of productive marshes and the introduction of pollutants through surface run-off at marinas and launching ramps are among these.

Indicators of biological sensitivity to boating activity and facility development were selected and mapped, along with the locations of marinas and public landings (launching ramps), which serve as loci of activity origin. Indicators of biological sensitivity include oysters, hard and soft clams, spawning areas of white perch and striped bass, rooted aquatic plants and coastal wetlands.

Carrying capacity formulae were found to offer promise in establishing management frameworks for accomodating use in estuarine systems, but were also recognized as being potentially disadvantageous where resource utilization may be brought to the brink of capacity and, consequently, to levels of adverse impact.

Boating operational requirements were evaluated and generalized norms of spatial use were identified for possible use in boating activity models.

Water body types were classified as to size, shape, and shoreline configuration; water bodies were identified as sub-bay units (estuarine tributaries) and management units (lesser tributaries).

The recommended boating capacity planning system, designed to deal with problems at the management unit level, is a set of eleven steps which modifies provisional activity models (boating "capacities") according to observable recreational and environmental constraints and establishes activity norms safely below user-dissatisfaction and environmental degradation threshholds. The revised activity model, together with water zone delineations, serve as guidelines for activity regulation and facility planning. Actual water zoning, speed and use-intensity regulations, and other measures, or the guidelines alone, may be selected to optimize need satisfaction within the management unit.

A recommended monitoring program is intended to alert management officials to the exceeding of the safety margins established by the activity models below capacity threshholds; this yellow flag status would require the institution of suitable temporary measures (e.g. speed and activity restrictions) until alleviation of the observed disturbance was secured. A red flag status would indicate severe disturbance and a need for yet greater restrictions.

Needs for further research were identified. Among these, investigation of methods for reliable measurement of boating impacts is foremost. Further research into the effects of flushing and circulation is also needed.

Part II of the study will deal with application of the boating capacity planning system to units of the Bays, the development of guidelines for boating facility planning and design, and the recommendation of suitable sites for new Maryland boating facilities.

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CHAPTER I

RECREATIONAL BOATING
IN THE STATE OF MARYLAND

THE BOATING SITUATION IN MARYLAND

Numbers and Distribution

Recreational boating activity in the State of Maryland is on the increase. During the past five years, the number of pleasure boats registered in the state has grown at an annual rate of roughly five per cent, from approximately sixty-two thousand boats in 1968 to over seventy-six thousand boats as of December 31, 1973. During the same period, changes have been taking place in the character of recreational boating activity. For a number of reasons, a higher percentage of Maryland boats are being kept at home and subsequently trailered to given access points every year. A parallel reduction is occurring with respect to the percentages of boats stored on the water during the recreational boating season. Although the absolute number of both trailer-boats and water-stored craft increased during the 1968-1973 period, the percentage of trailerboats grew from 35% of total registrations to 46%, while the percentage of water-stored craft declined from 64.4% to 52.9%.

In terms of distribution of boats registered in the bay area, the most specific figures currently available are those listed in the DNR Boating Administration's 1973 Boating Report (227). As summarized in the report, the major concentrations of homeport registered boats are located in the northern regions of Chesapeake Bay. The counties bordering the bay in this area, Anne Arundel, Baltimore, Harford, Cecil, Kent, Queen Annes, and Talbot, serve as the homeports for almost 40% of the boats registered within the entire state

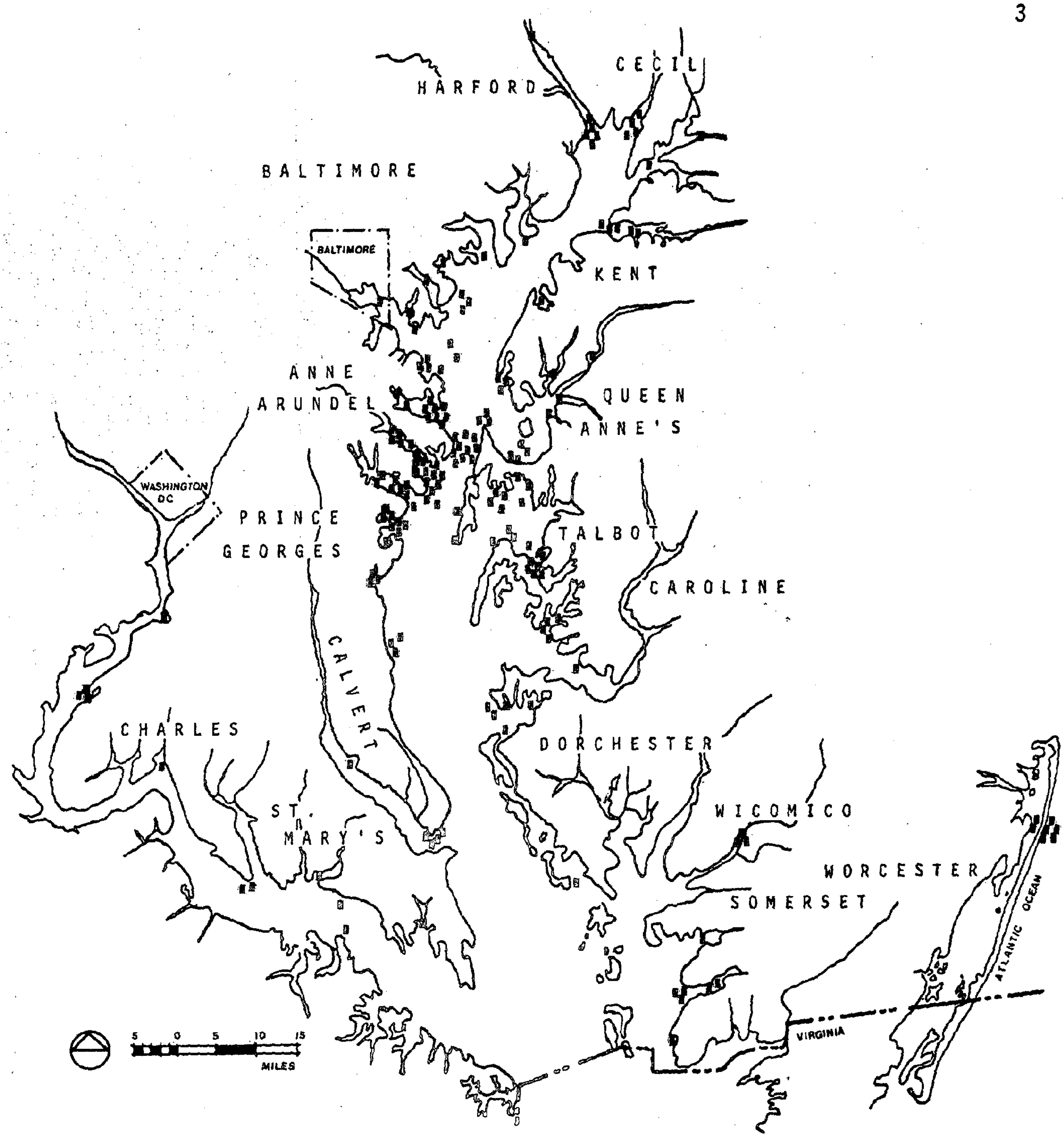


Figure 1: Location of Boating Accidents, 1971-1973, from the Marine Police boating logs.

of Maryland. This concentration of boating activity is further borne out by the 1973 boating accident data as depicted on the accompanying map (Figure 1). Assuming numbers of accidents should correlate fairly well with levels of boating activity, the map provides an indication of the location of the most heavily used areas of the Bays.

In addition to the numbers of boats registered in Maryland homeports, the bay is often frequented by boaters from other states and by boaters using unregistered boats. Results of the 5th district Recreation Boating Population Statistical Information Survey(166), undertaken by the Coast Guard in 1971, indicate that 5% of the boaters using the bay area enter the bay from out-of-state areas, namely Virginia, the District of Columbia, West Virginia, and Delaware. In addition, the Coast Guard estimates the ratio of numbered and registered boats to total owned boats at 82% (217). Thus, a significant number of non-registered boats can be expected to be utilizing the bay waters at any one time.

As a result of the inadequacies inherent in using boat registration data specific only to county levels, current efforts are underway by the DNR Boating Administration to develop key-coded maps for identifying specific locations of registered boats. These maps are expected to be available in mid-December 1974, and will constitute an important data source for Phase II of this study.

Registration and Titling Regulations

The above figures primarily reflect data on boat registration compiled prior to January 1, 1974. Until then, the Federal Boat Safety Act of 1971, all boats had to be registered if: 1) propelled by an engine of more than 7.5 hp or 2) propelled only by sail, and over 25' in length. This data thus excluded, as noted above, highly mobile boats (by trailer) powered by small outboard engines, as well as small sailboats. Given the number of these small, inexpensive boats, a substantial part of the boat population was not included in the statistics--a major shortcoming, as data of this type is of prime importance relative to the provision of public access sites. The existing law was subsequently modified by the registration authorities, requiring that after January 1, 1974, any boat propelled in whole or in part by propulsion machinery of any type must be registered with the State. This revision alleviates the earlier inadequacies to some extent; however, all small and unpowered sailboats remain unaccounted for. These form an important component of the demand for public launching areas and for some mooring capacity.

Prior to registration, all boats are required to be titled by the State of Maryland. Titling procedures for boats are analogous to procedures used for automobile titling. Once properly titled and registered, boats are issued numbers which must be appropriately displayed on the hull.

In Part II of this report, boating demand projections for Chesapeake and Chincoteague Bays will be presented; the findings will enhance the ability of the State to plan wisely for both new boating facility construction and the regulation of boating activity.

Use Regulations

According to the Maryland Boat Act of 1960, amended 1971, Article 14B of the Annotated Code of Maryland, several laws have been passed regulating boat use. As set forth in Section 08.04.00.01-Rules and Regulations promulgated by the DNR Boating Administration, these regulations cover a range of boating operational uses including negligent operation, litter probibition, noise muffling and "rules of the road". Of particular importance to the purposes of this study are the sections regulating waterskiing and speeding. Regulation 08.04.00.15 establishes speed limits of 6 knots for weekend and holidays, for various areas where congestion, erosion resulting from boat wake and other problems exist. The primary criteria in the past for establishing these zones has been navigational safety as determined by the DNR and Marine Police upon receipt of complaint petitions. Future criteria hopefully will include: noise, intrusion of privacy, shoreline erosion, and other factors. Regulation 08.04.00.15 establishes permanent speed limits of 6 knots in other areas as well. Specific locations for the imposition of these speed controls can be found in the Boating Administration's Rules and Regulations 08.04.00.01 and subsequent amendments. These zones have been mapped by the state planning office on U.S.G.S. maps at a scale of 1:25,000. (The maps also include crab lines, oyster bed lines, buoys, etc.)

Additional regulations control waterskiing. Under these, the towing boat must maintain a distance of at least 100 feet from shore, and skiing is prohibited between sunset and sunrise. (228).

Marinas and Other Boating-Related Facilities

Associated with the increasing numbers of boats in the bay region are the increasing numbers of facilities providing services for boat launching, storage and maintenance. These facilities include: private marinas offering slips, moorings and other facilities; public marinas operated by town, state or county governments; private docks and ramps; facilities exclusively for sailboats; and public launching ramps and docks. Some of these larger facilities may also provide boat rentals, food services, shops and other services.

As of December 31, 1973, there were over 37,000 registered trailerboats in Maryland, and over 44,000 boats registered and kept in the water. The supply of marina berths has historically been insufficient to accommodate demand, and the gap seems to be widening. Most Maryland marinas currently operate at or near full capacity, with long waiting lists for available berths. There is also a growing shortage of sufficient public access sites. A 1972 survey identified 123 public landings in 11 Maryland Bay shore counties. Of these, 82 had boat launching ramps, 26 consisted only of roadways stopping at the water's edge, 12 were fishing piers, and 2 were relatively sophisticated harbor and/or shop facilities (229). With an absolute minimum of 37,000 trailerboats, a shortage of public access sites is clear (as an example, Anne Arundel County, with 5,092 registered trailerboats, has only one public launching ramp).

The location of marinas and other boating-related facilities have been mapped by RMA and will be utilized in Phase II of this study. Descriptions and locations of the facilities can be found in the 1974 Boating Almanac (210) and the DNR publication Problems Associated with Public Landings, 1973 (229).

Regulations Affecting Marina and Boating-Related Facility Construction

Prior to construction of marina facilities in the State of Maryland, several licensing and permit requirements of the Federal, State and local levels must be satisfied. These requirements generally fall into four categories:

1) Federal permits relating to the obstruction of navigation,

2) State Wetlands Licenses related to the dredging, filling or other alteration of wetlands,

3) State certificates and permits relating to water quality standards and sediment control,

4) Local zoning ordinances and land use controls.

Federal Permits: Under the Federal Rivers and Harbors Act of 1899, the Army Corps of Engineers has responsibility for evaluating requests to make physical alterations in navigable waters. Issuance of such permits is subject to veto by local and state agencies. In addition, under the NEPA of 1969,[1] the filing of Environmental Impact Statements may be required where the potential for environmental degradation exists.

State Wetlands Licenses: Title 9 of the Natural Resources Act of the Revised Code of Maryland requires that a license be obtained from the Board of Public Works for the dredging, filling or other alteration of state wetlands. State wetlands are defined to include: "any land under the navigable waters of the State below mean high tide." (NRS9-101(M)). Guidelines for approval of activities occurring in state and private wetlands were established in 1973 by the DNR.

State Certificates and Permits Relating to Water Quality and Sediment Control: Pursuant to Section 401 of the Federal Water Pollution Control Act, the Water Resources Administration of the DNR is responsible for issuing or denying a Water Quality Certificate where ambient water quality or effluent discharge limitations may be violated. Secondly, under Title 8 of the Natural Resources Article of the Revised Code of Maryland, grading and sediment control plans must be reviewed and approved by the appropriate soil conservation district authorities prior to construction.

[1]National Environmental Policy Act of 1969, PL 91-190.

Local Zoning Ordinances and Land Use Controls: Where they exist, local zoning ordinances and controls must be abided by to prevent congestion, violation of riparian rights, obstruction of navigation, or violation of zoning codes. For example, the Maritime Group A Districts zoning ordinances approved and enacted in 1971 by the City of Annapolis established specific constraints regarding the looation and design of commercial marinas, community marinas, and yacht clubs. In addition, riparian rights - access to navigable waters by owners or riparian lands must be adequately considered.

An excellent case study of the process involved in obtaining the necessary approval and permits for constructing marinas is presented in the Chesapeake Research Consortium's 1974 Special Report on a Corps of Engineers permit application for Watergate Village, Annapolis. A study of existing and proposed legal regulations on boating and related facilities will constitute a major component of the research reported in Part II of this report where they will be more carefully analyzed and discussed.

PROBLEMS AND CONFLICTS ASSOCIATED WITH INCREASED BOATING ACTIVITY

Problems Related to User Satisfaction

Subjectively, it is easy to identify the undersirable impacts of increased levels of recreational boating as far as user satisfaction is concerned. As boat numbers grow, boaters suffer losses of satisfaction from being forced to operate on crowded waterways. In addition, access roads and public launchings become crowded, while marina storage and repair services are in even shorter supply. Finally, navigational safety decreases with greater numbers of operating boats.

Most instances of boating congestion in the Chesapeake and Chincoteague Bay systems have been reported in the tributaries of Chesapeake Bay, particularly in the narrower arms and creeks of the South, Severn, and Middle Rivers and in the nearshore open waters of both Bays.

In the tributaries, where most boating facilities are located, congestion may be due to excessive proximity of marinas to the channel or thread of the waterway, excessive numbers of marinas in low capacity water bodies, under-design of marinas in terms of inadequate fairway width, lack of expansion space for new berths, and poor marine service station location, location of boating facilities mooring fixed-mast or high-clearance craft upstream of bridges, excessive distances of boating facilities from targeted boating, sailing and fishing waters, inadequate separation of launching ramps and moorings, excessive proximity of recreational boating to commercial fishing and shipping, physical constrictions to the passage of craft--such as at Knapps Narrows--and use restrictions--such as waterskiing prohibitions--which tend to concentrate activity in non-restricted areas.

Congestion in nearshore open waters occurs infrequently and may result from combinations of circumstances, such as the arrival of a large number of small and moderate sized craft at the mouth of a tributary on a fair-sky day and the development of moderately rough waters which would tend to keep them close to shore.

As noted earlier, there have been significant increases in the numbers of boats kept at inland homes and transported to the bay shores via trailer or car top carriers. This trend in boat storage and mobility, together with increases in other shoreline recreation pursuits, have subsequently resulted in overcrowding of access roads to public launchings and marinas. The problem is particularly significant in the bay area where there exists a large number of drawbridge river crossings. As boat traffic increases on the rivers and bay tributaries and automobile traffic increases on the bridge crossings and access roads conflict grows between boat and automobile usage of the drawbridges. It is estimated that the increase in auto and boat usage generated by water-oriented activities could result in a 40-50% increase in the number of openings for 8 of the most active bridges over the next 20 years. Thus similar increases in car stoppage can likewise be expected (217). As pointed out in the 1973 Study of Problems Caused by Drawbridges to Motor and Water Traffic (217), the location of marinas and launching sites will strongly influence the amount of boat traffic requiring the raising of bridges as well as the amount of automobile traffic utilizing the crossings. These problems will be considered in more depth in Phase II of this project.

The existing shortage of marina and launching facilities poses further problems for boat user satisfaction. At present there are proposals in varying stages of approval for facilities at Sandy Point (proposed storage: 250 boats), Point Lookout, and Rocky Point (proposed storage: 624 boats), but these are of moderate size. The shortage is likely to induce pressure for the development of large-scale regional facilities, particularly on the western shore of the bay, where only six public launching ramps exist from the Susquehanna to the Patuxent. Large marina facilities, on the order of magnitude of Marina Del Rey in Los Angeles (approximately 6,500 berths in 1974), raise important questions relating to the sacrifice or the spoiling of natural areas for the improvement of facility efficiency and boater satisfaction. Marina construction, which may involve the filling, dredging and bulkheading of wetlands; concentrated sanitation disposal and oil spillage in sensitive ecological areas; and visual and aesthetic intrusions at the shoreline; will have to be planned to provide optimized user satisfaction consistent with full environmental protection.

Future problems may also ensue should an increase in the use of offshore moorings occur. The potential navigational hazards posed by the use of such moorings, together with the existing widespread use of individual and communal finger piers may further contribute to the crowding and congestion of narrow coves and waterways, although in many cases such structures have not been incompatible with the through passage of boats.

Another problem relating to user satisfaction as boating numbers increase are the use conflicts and decline in navigation safety resulting from congestion and crowding of waterways. The chart below (Figure 2), illustrates the increase in number of boating accidents relative to the increase in boating activity. These figures show an increase in the number of accidents over the ten-year period from 1963 to 1973 of about 30%. However, it is estimated that these figures pepresent only one-fourth of the total number of accidents occurring, the remainder having been unreported.

As was shown in Figure 1, accident locations over a four year period indicate significant congestion at the South, Severn, Magothy, Miles, and Patuxent Rivers; in Eastern Bay; and in the vicinity of Ocean City at Chincoteague Bay. These accidents can be largely attributed to conflicts

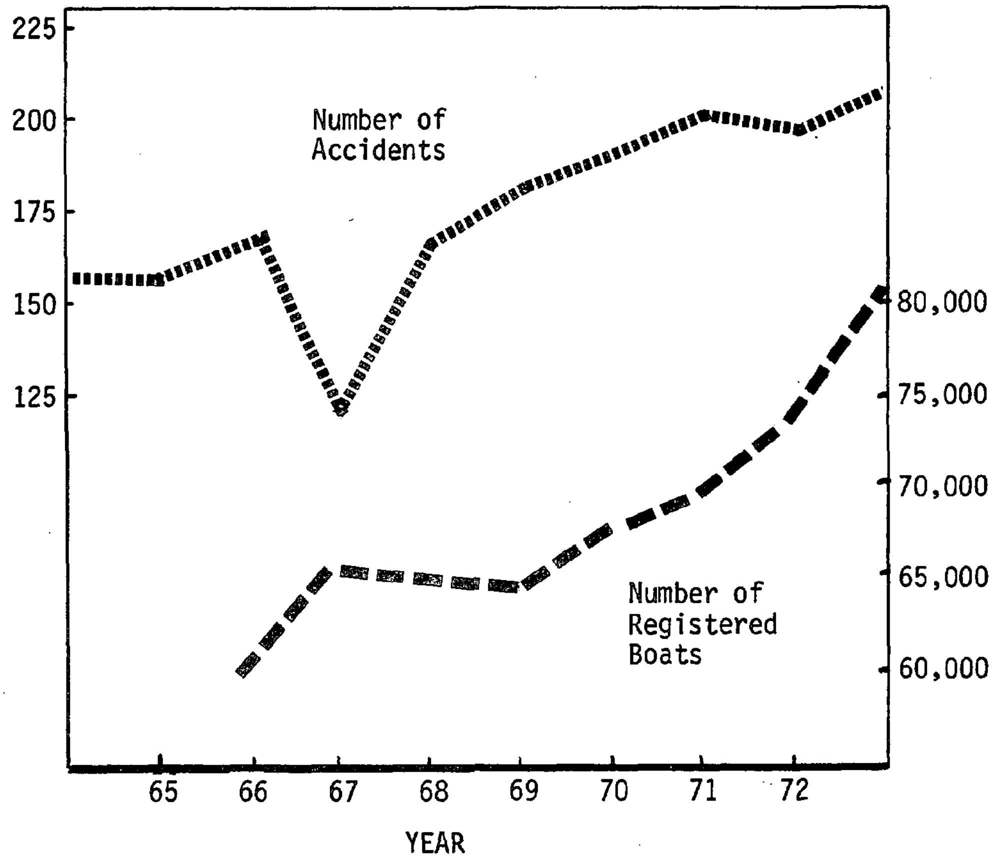


Figure 2: Relationship of Increases in the Number of Registered Boats to the Number of Boating Accidents

resulting from negligent operations of high speed boats and congestion resulting from the use of the same waters by boats of different types: sail, cruising, fishing, and skiing.

Problems related to degradation of environmental quality

From an environmental perspective, the operation of large numbers of boats may lead to degradation of water quality under certain conditions; more boats operate in a given area, and other boats utilize new water surfaces as they attempt to escape the overcrowded conditions. Specifically, water quality may suffer from the input of engine exhaust gases, from oil and gasoline spills, from the dumping of human waste and other debris, and from turbidity caused by propeller wakes. In turn, negative changes in water quality levels lead to altered and degraded patterns of aquatic life and shoreline vegetation. Similarly, shoreline erosion can be exacerbated by the wakes of boats operating at high speeds. Finally, the construction, maintenance, and operation of shore-support facilities, such as marinas, may create adverse environmental impacts in the form of sedimentation and depletion of marsh biomass.

The relationships between measurable changes in the quality of the environment and the boating-related factors which caused them to occur are quite complex. However, in general terms, the relevant processes are as follows. At the first level, socio-economic and demographic characteristics of the boating population combine with the available supply of water bodies and required facilities, to determine boating use types and levels for a given area. Then, boating use considerations will mandate specific boating operational parameters. For example, waterskiing demands high speed operation, high power-to-boat weight ratios, operation close to the shoreline, and often a pattern of several outings, each of short duration. Conversely, sport fishing may call for slow to moderate speeds and operation further from the shore, while leisurely fishing may involve anchoring of the boat for long periods, or drifting slowly with the current. In turn, the specific operational parameters which result from use, boat, and engine types determine the absolute amounts of given impact factors. As examples, the amounts of oil, gasoline, and exhaust gas discharges from a particular boat are a direct function of engine type and size, boat type and size, operating fuel/oil ratios, condition of engine tune, and other considerations. Similarly, the amount of waste and debris discharged by boats is related to the boat's capacity to store the wastes, to the availability of proper shore disposal facilities, and to the duration and purpose of the specific outing.

Demand, type of use, and operational parameters combine to determine levels of given impact causative factors, however the physiographic and biological characteristics of the receiving water body will determine the susceptibility of water body to degradation. Changes in environmental quality are ultimately determined not by absolute levels of casuative factors, but by their chronic concentrations over time, and by the susceptibility of specific elements in the ecosystem to such levels. Physiographic characteristics, such as tidal flushing rates, will translate an input of <u>x</u> gallons per day of oil into embayment <u>y</u>, into the long term ambient level of hydrocarbons in that water body. Similarly, the relative presence or absence of species A, B, and C and their specific susceptibilities to oil by-products, will determine the net environmental response in the embayment in question, to the original level of oil spills.

Thus the impact on the environmental quality of Chesapeake and Chincoteague Bays resulting from recreational boating activities must be viewed in context with the effects produced by other contributors affecting the environmental quality of the bay. Primary among these contributors are the discharge of industrial and domestic wastes, increased runoff and sedimentation resulting from urbanization, and oil spillage from commerical shipping.

Dredging for channel maintenance also may cause significant resuspension of fine materials and the subsequent smothering of shellfish and shellfish beds.

Contributions from industrial wastes may vary from non-toxic rinse water or cooling water to extremely harmful chemicals, heavy metals, and oil and grease. Dishcarge from municipal sewage or individual homeowner septic systems introduce excessive loads of nutrients on the bay system which may in turn result in algal blooms, decreases in dissolved oxygen, and other alterations affecting the species composition and productivity of the bay waters.

The increased percentage of impervious surface areas and exposed soils resulting from the clearing, cutting, and filling practices associated with urbanization have greatly increased the sedimentation load entering the Bay's tributaries. This increase in sedimentation further induces the need for channel dredging operations which may in some instances adversely affect the water quality of the bay.

The shipping activities associated with the Port of Baltimore and other commercial facilities in the bay area additionally affect the water quality of the bay. Oil and fuel spillages and the leaching of heavy metals from anti-fouling paints introduce large concentrations of toxic substances into the harbor water. The circulation of these substances throughout the bay waters will be largely determined by the currents and flushing rates. Removal and disposal of dredge spoil for channelization maintenance may produce changes on the topography, current, salinity, tidal volume, sediment load, turbidity, and marina biota and environment, producing significant ecological shifts.

All of the above contributors will generally influence the water quality of the bay to a much greater extent than the impact of recreational boating. However, where high concentrations of boating activity exist, there may be significant localized effects such as shoreline erosion resulting from the impact of boat wakes or alterations in marine biota produced by oil spills in the vicinity of marinas. As of the present time, no comprehensive findings exist regarding the complex interrelationships between contributions to the level of water quality from recreational boating and the other above-mentioned sources. Under the Federal and state water quality acts, the EPA and the State of Maryland Water Resources Administration are undertaking continuous monitoring and assessment of the water quality of the bay region. When the results of these studies become available, supplemented by further monitoring and research, a determination of the baseline data can be made, and a more fundamental understanding of the significance of recreation boating impacts on water quality relative to other contributors will be possible.

CHAPTER II

INTRODUCTION TO THE CONCEPT OF CARRYING CAPACITY

DEFINITIONS

The term "carrying capacity" refers generally to the level of use or extent of modification an environmental system may bear without experiencing degradation. The term and concept have been most widely employed to define levels of wildlife populations, grazing, cropping, or change which can be managed without diminishing the sustained yield an environmental system is capable of producing.

The concept has been valuable in management practice in preventing over-use of productive environments. It may, however, also lead to inadvertent over-use, if resource utilization is allowed to reach the brink of capacity. As pointed out in the Conservation Foundation Letter of May, 1974, "Any identification of an area's carrying or holding capacity is an invitation to use or fill that capacity." This is particularly possible in areas of environmental management in which reliable scientific data on resource degradation are not easily obtained or field parameters easily monitored. It is also very possible where sensitivities of resources to use and change undergo large fluctuations or differ locally to a great degree.

Recreational boating is one such area. It will be clearly valuable to prevent over-use or mis-use of water surfaces in the Maryland Bays, in terms of both user satisfactions and environmental protection, and it will be valuable to provide expanded boating opportunities in sub-areas of the Bays in which an excess capacity exists. Yet the key to environmental protection in a carrying capacity management framework--monitoring and analysis of environmental responses to identified causative factors (such as the detection of accelerated bank erosion resulting from the wakes of speeding motorboats)--is difficult to achieve in the complex water-land-biota make-up of estuarine systems. And the sensitivities of Bay resources to boating use will fluctuate widely according to season, water temperature, tidal stage, presence of other uses, and many other factors. The aesthetic sensitivities and recreational expectations of Bay users will also vary widely: cruising in the quiet slackwaters of Talbot County in contrast to cruising down the Severn River on a busy weekend day; fishing with a dropline in a small creek in contrast to fishing for rockfish or blues in the open Bay. It is, in fact, this variance of uses, sensitivities, and expectations that sets the stage for the occurrence of over-use and conflict, both among boaters and other aquatic recreationists, and between aquatic recreationists as a group and other users of the waters and land edges of the Bays.

Carrying capacity, which may also be termed "holding capacity" or "optimum use level", can be interpreted to be or implemented in terms of the numbers of users of the resource in question, the uses which may be allowed in a given resource area, or the intensity of use which may be permitted.

Numbers of Users. Regulation of the numbers of users of a given resource is not uncommon. State game managers regularly count deer populations; deer hunting seasons are adjusted or other measures are instituted to reduce excess populations which cannot be supported by the available browse or food supply. Certain public beaches are protected from excessive numbers of users by restricted availability of parking spaces and prohibition of roadside parking.

In terms of recreational boating, some self-regulation exists by virtue of the location and berth capacities of marinas and private facilities. The exercise of marina construction permit approvals and denials by the U. S. Army Corps of Engineers and the Maryland Department of Natural Resources as well as the state park marina and public launching ramp programs of the latter agency also impose a degree of regulation over the number of users (expressed in terms of boats) originating in given sub-areas of the Bays. However, the available data on congestion and accidents, reviewed earlier, indicate that a large part of the capacity problem lies not in the actual location of moorings and launching ramps, but in the patterns of passage, activity, and conflict that occur throughout many limited or constricted waterbodies--in which both Bays abound.

Permitted Uses. The regulation of uses in given areas is a common application of the so-called police powers. Land-use zoning is the most familiar form of this institution. Water-use zoning, although applied in limited instances, is practiced in one form or another in virtually all of the states. The most commonplace example of water-use zoning is the exclusion of water-skiing from certain sections of waterbodies, or entire waterbodies in instances of small size or of other sensitivities. In Maryland, under Regulation 08.04.00.15 of Article 14B of the Annotated Code of Maryland, water-skiing is excluded from certain small sub-areas of Chesapeake Bay, for example on Alms House Creek on South River. Such use exclusions have been instituted for weekends and State holidays only, or apply at all times. Threinen (192) reports the development of zoning of wild and semi-wild water zones along the near-shore edges of Wisconsin Lakes, within which motorboating is prohibited. Mann (178) proposed water-use zoning of the Charles River Basin in 1967 in order to diminish conflicts between powerboat passage from upstream yacht clubs to Boston Harbor and sailing and crew activity. Water-use zoning is an important potential tool for optimizing user satisfactions but cannot be implemented without the exercise of care in accommodating all user needs with equal, albeit separated, opportunity. Jaakson (194) proposed zoning of Reid Lake into three areas to satisfy the demand range and termed them Shoreline Activity Zone, Open Water Zone, and Wilderness Zone.

Intensity of Use. Use intensity is an expression of activity impact. It is congruous with density, or numbers of users, only when all users are at low levels of action, or moored. As motorboats increase speed, water-skiers take longer and wider runs, or sailboats group into favorable sailing waters, greater potential for conflict, congestion, and impact occur. A common tool for regulating intensity of use in managing fish and game populations is the prohibition of the taking of female (deer, crabs) or undersized specimens (deer, fish, crabs) or of numbers of specimens in excess of a "bagging" limit. In recreational boating, intensity use is commonly regulated through the imposition of speed limits and of rules forbidding high wakes in the vicinity of moorings. Use intensity regulation has potential for further application, particularly in the development of new speed zones in sensitive areas and possibly, new limit categories. Additional potential also exists in the possibility of additional marine police surveillance and in the imposition of temporary separations of use in areas where unusual use-intensity occurs.

It is obvious that in terms of recreational boating in Maryland tidal waters, numerous effective tools presently exist and are being utilized to both extend boating opportunities to optimum levels and prevent over-use or misuse of sensitive areas. Management applications of new carrying capacity determinations, therefore, should as a first step maximize utilization of these tools. What is needed to supplement them is a new mechanism to aid in facility planning, on the one hand, and in use and intensity regulation, on the other, in order to optimize recreational satisfaction while preventing environmental degradation.

CRITERIA FOR A BOATING CAPACITY PLANNING SYSTEM

In order to meet Maryland's goals in both recreational boating and environmental protection, such a system would have to:

1) Identify the presumed recreational boating carrying capacity of individual sub-areas of the Maryland Bays. This initial determination should be made on the basis of boating and user needs. The specific criteria for spatial needs of boating activity are explored in Chapter III of this report.

2) Identify environmental sensitivities and the indicators which reveal the points at which recreational boating may have adverse effects on them. These are explored in Chapter IV. The identified indicators, shown also on the report maps, should be used to trigger alerts to the exceeding of the environmental carrying capacity of the area or areas in question.

3) Set limits of user numbers, permitted uses, or use intensities at levels safely below threshholds of user dissatisfaction and environmental degradation. In order to prevent inadvertent occurrences of intolerable congestion or of adverse environmental impact, the mechanism should incorporate limits at levels well below dissatisfaction or degradation threshholds.

4) Provide for new facilities or suitable locations of excess carrying capacity up to the presumed safe limits.

5) Encourage and regulate the lessening of use or intensity in areas or at times of deficit carrying capacity or when environmental degradation attributable to recreational boating may occur.

6) Be flexible, pragmatic, and adaptable for use by public officials responsible for boating activity and facility construction decision-making.

In order to explain the system that is proposed by this report, a review of recreational boating operational and facility requirements, and of bio-physical environmental sensitivities is presented on the following pages. The system itself is presented in detail on page 100.

CHAPTER III

BOATING OPERATIONAL AND SPATIAL REQUIREMENTS

INTRODUCTION

This section will examine boating operational parameters and related facility requirements as they relate to the determination of carrying capacity criteria for application in the field of recreational boating resource management. Primary emphasis will be placed on the design and performance characteristics of the different boat types since these characteristics constitute the most significant criteria for planning purposes. Shore access requirements and facilities related to recreational boating will be discussed since the planning of these facilities will greatly affect user satisfaction and environmental quality at the water-land interface.

DESIGN AND PERFORMANCE

The specific surface area needs of a given pleasure craft in a particular outing will be a function of three principal sets of factors:

1. boat type, size, and power class
2. activity type and operation requirements
3. navigational and external constraints

The interactions among all these variables are highly complex, but a general classification system has been developed for the purposes of this study. This system will be discussed in the following sections.

1. Boat Type, Size, and Power Class

The implications of design and performance specifications can be considered for the five categories of boats established by the State of Maryland Boating Administration for registration purposes: runabouts, cruisers, auxiliary sail, sail, and other craft.

Runabouts are small, open boats, designed to be used principally with outboard motors. Runabouts are generally not more than 25' in length, are fast and highly maneuverable, and are principally used for racing, day cruising, and waterskiing. In 1973, runabouts accounted for 58.2% of all registered boats in the State of Maryland.

Cruisers have some enclosed cabin area, range from approximately 20' to 50' in length, and constitute the next largest group of registered boats in Maryland --22.0% in 1973. Cruisers generally operate at speeds lower than those of runabouts; small cruisers tend to use outbaord engines while larger ones tend toward the use of inboard or inboard/outboard drive combinations. Principally, cruisers are used for day and long distance cruising, and sport fishing.

Auxiliary Sailboats are sailboats which are equipped with an auxiliary engine for propulsion, usually used only when entering or leaving port or under weather conditions unsuitable for the use of sail. In 1973, auxiliary sailboats accounted for 3.5% of all boats registered in Maryland. Few sailboats under 25' are equipped with auxiliary engines, since these craft are mostly used in protected waters and are generally not built for engine adaptation.

Sail boats include a wide variety of craft, from small portable boats which may be carried on the top of a car, to large schooners and sloops. Under past and present boat registration procedures in Maryland, accurate counts of sailboats have not been required. Estimates range from 5,000 to 25,000. Mainly sailboats are used for day cruising and racing. Their lower speeds and lower maneuverability, relative to power craft, grant 'rules of the road' priority to sail under almost all conditions.

The other boat category includes skiffs, johnboats, rowboats, and other boats often used for leisure fishing, or for maintenance of and access to other recreational vessels.

The table on the following page summarizes generalized use and operational characteristics of the various categories.

2. Activity Types

Given the great variability among design and performance specifications, together with the fact that the operational demands of different activity types reduce that variability, it appears that operationally oriented carrying capacity criteria should be based on activity type considerations, rather than on specific boat types. Put another way, there is more similarity between the actual characteristics of two boats--different in length and horsepower--which are both engaged in waterskiing, than between two identical boats: one pulling a skier and the other out for a day cruise. For this reason, it is critical to examine the relationships between boating operational parameters and various activity types. For analytical purposes, six principal activity types have been identified; speedboating, waterskiing, sportfishing, leisurely fishing, cruising, and sailing. The latter two are subdivided into day cruising and sailing, and long distance cruising and sailing.

Speedboating is generally done in relatively high powered runabouts designed for that activity. The principal satisfaction derived from this activity is the sensation of speed and power felt by the boater. Speedboating by its nature, demands high speeds of operation, usually in excess of 20 mph. Speedboats are highly maneuverable, and require relatively large amounts of water surface. Speedboating tends to take place from later morning through the mid-afternoon, and is often marked by a complex outing course, since the boater will want to take advantage of the speed and maneuverability of his craft.

Waterskiing displays many of the same operational characteristics as

PHOTOGRAPHS

Table 1

BOAT TYPES	Speed	Maneuver-ability	Surface Area Req.	Outing Range	Distance from Shore	Length	Prop. Type	hp	Storage Type	Shore Access
	OPERATIONAL/PHYSICAL PARAMETERS									
RUNABOUTS	M/H	H	L M H	L/M	L/M	0-28'	O,I (I-O)	15-125	T A S	R H
CRUISERS	M/H	M/H	L M H	M/H	M/H	16-65'	I (I-O)	40+	S A T	H R
AUXILIARY SAIL	L/M	L/M	L M	L M H	M/H	0-65'	S (I-O) O	0-40'	S A T	H R
SAIL	L/M	L	L M	L M H	L-H/ M-H	0-65'	S	--	T S A	R H
OTHER	L/M	M/H	L/M	L	L/M	var.	O (I-O)	var.	A S T	R H

LEGEND:

Speed: L: Low, 0-6 knots; M: Meduim; 6-12 knots; H: High, over 12 knots
Maneuverability: L: Low; M: Meduim; H: High; based on general turning and stopping capabilities
Surface Area Requirements: L; Low, 0-4 AC/Boat; M: Medium, 4-8 AC/Boat; H: High, over 8 AC/Boat
Outing Range: L: Low; M: Medium; H: High; relative values only, as outing ranges are highly variable within the boat types
Distance from Shore: L: Low, 0-1 mile; M: Medium, 2-5 miles; H: High, over 5 miles
Propulsion Type: O: Outboard; I: Inboard; I-O: Inboard/Outboard
Storage Type: T: Trailer; A: Anchor; S: Slip; listed in descending order of use
Shore Access: R: Ramp; H: Hoist; listed in descending order of use

speedboating, including high speeds (23-30 mph) and the need for a high amount of surface area. However, due to the presence of the skier, the course of a boat engaged in waterskiing will tend to be more contained and less erratic. An open course one half mile in length and 200 yards wide will be considered satisfactory by most average skiers. The presence of the skier, with his towline, makes the boat-skier combination much less maneuverable than a speedboat alone, and consequently more prone to the occurence of accidents.

Sportfishing refers to the use of larger craft, such as cabin cruisers, to catch gamefish in the deeper and more open reaches of the Bay system. Sportfishing is done at moderate speeds, and displays long and moderately complex outing patterns, which generally takes the sportfisherman a large distance from the shoreline. A boat engaged in sportfishing requires a moderate amount of surface area, but at the same time seeks to stay as far as possible from other boats engaged in the same activity.

Leisurely fishing refers to the use of small boats for slow speed fishing in river and creek areas. The leisurely fisherman will use a small boat, with a low to moderate sized engine (usually less than 25 hp), will require a small amount of surface area on which to operate, and will have a short and localized course pattern. In addition, the leisurely fisherman will spend long periods of time at anchor or just drifting with the current.

Cruising, as an activity, has two underlying motivations: the desire to go somewhere, and the fun of getting there. Although there are exceptions to every rule, a boater out for a cruise will have a more clearly defined route objective than a speedboat, and will plot a less random course. Cruisers will tend to operate at lower speeds and be less maneuverable than speedboaters.

The distance from the shore and the overall trip length and complexity of a given cruise will be influenced by whether the given boater is out for a day cruise, or for a more extended journey. In turn, that cruise will be largely influenced by the characteristics and capacity of the individual's cruiser.

Sailing is unlike power boating in that a majority of the time is devoted to operating the craft, to the exclusion of most other activities. Consequently, the sailor is normally more concerned with proper operation of the craft than with speed performance or destination. Sailboats operate at low speeds, have low maneuverability, and display patterns of operation marked by long runs and relatively frequent changes of course (tacking). With the predominance in Maryland of small, portable sailboats, most of the activity of these boats is of the day sailing variety.

The chart below summarizes the important operational characteristics of the boating activity classes just described:

Table 2

ACTIVITY CLASSES	OPERATIONAL CHARACTERISTICS					
	Speed	Maneuverability	Area Req.	Outing Range	Distance from Shore	Boat Size
SPEEDBOATING	H	H	H	L/M	L/M	0-40
WATERSKIING	H	M	H	L/M	L	0-26
SPORTFISHING	L/M	M/H	L/M	M/H	L	16-65
LEISURELY FISHING	L	H	L	L/M	L	0-26
CRUISING (POWERED)						
A. DAY CRUISING	L/M	M/H	L/M/H	L/M	L/M	0-65
B. LONG DISTANCE CRUISING	L/M	M/H	L/M/H	M/H	L/M/H	26-65
SAILING						
A. DAY SAILING	L	L	L	L/M	L/M	0-40
B. LONG DISTANCE SAILING	L/M	L	L/M	M/H	L/M/H	26-65

LEGEND: L: Low; M: Moderate; H: High

Operational Surface Requirements

As specified in the preceding discussion, each of the boating activity types have certain boating operational characteristics. These operational characteristics in turn require varying amounts of water surface area to ensure boater satisfaction. The surface area requirements constitute the major carrying capacity criteria for planning purposes to be utilized in Phase II of this project.

In the past few years, as the management of recreational boating activities has received increased attention, planners have attempted to come to grips with the question of selecting carrying capacity criteria for planning purposes. A thorough review of these presently available standards reveals a wide variation among estimates, a fact reflective of differing planning processes, and to a lesser extent, of different areas of study and concern (lakes versus rivers, for example). The available standards are summarized on the accompanying chart. Despite the variability, some useful trends do appear, especially as regards to both waterskiing and powerboating. With waterskiing, ten acres per boat appears to be a workable minimum, with 20 acres per boat as a very desirable "normal" condition. Turning to powerboating, an acceptable range of densities would seem to run from a low of 3 acres/boat to a desired level of 10 acres/boat.

It must be kept in mind that any estimates of this type are just planning guidelines which must be further refined to correspond to localized boating use and environmental parameters. In addition, the meaning of a density range must be kept in its proper perspective. To say that waterskiing requires a minimum of 10 acres/boat, and has a "normal" or "desirable" level of 20 acres/boat

Table 3

Survey of Currently Utilized Surface Area Standards By Recreational Boating Activity Type

ACTIVITY	SOURCE	FRAME OF REFERENCE	DERIVED STANDARD (ACRES/BOAT, EXCEPT WHERE OTHERWISE NOTED*)	COMMENTS
WATER SKIING	Army Corps of Engineers[1]	rivers	1	includes all power boating
	N.A.R. Study[2]	all	1-1.5	
	Soil Conservation Service[3]	all	5	
	Boating Industries Assoc.[4]	all	10-12	
	Ontario[5]	lakes	20	based on observation
	Wisconsin[6]	lakes	20-40	based on observation
	Louisiana[7]	all	40	
FISHING	Army Corps of Engineers[1]	rivers	.02	
	Soil Conservation Service[3]	all	.14-.50	
	Wisconsin[6]	lakes	8	based on observation
SAILING	Soil Conservation Service[3]	all	3	
	Bureau of Outdoor Rec.[8]	all	3	
	N.A.R. Study[2]	all	3-9	
POWER BOATING	Army Corps of Engineers[1]	all	1	includes skiing
	Bureau of Outdoor Rec.[8]	all	1.5	includes non-powered
	California[9]	all	1.6	non-trailer only
	N.A.R. Study[2]	all	1-2	under 20 hp
	Soil Conservation Service[3]	all	3	includes sail
	N.A.R. Study[2]	all	3-9	inboards & outboards>20 hp
	Placer County[10]	lakes/rivers	5	trailer boats
	Ontario[5]	lakes	10	
	Wisconsin[6]	lakes	10-20	
	Louisiana[7]	all	20	
ROWING	N.A.R. Study[2]	all	.33-1	
CANOEING	Wisconsin[6]	streams	1/2 mi/canoe*	
	Louisiana[7]	streams	1/2 mi/canoe*	

[1]U. S. Army Corps of Engineers, Design Criteria for Recreation Requiring Water Surface: Grand Chariton and Little Chariton Rivers Report, Kansas City, Missouri.

[2]North Atlantic Regional Water Resources Study, Appendix M, Outdoor Recreation, May 1972.

[3]Soil Conservation Service, U. S. Department of Agriculture, Recreation Memorandum -3, Supplement -3 (Re: Ratios and Distances Between Land, People, and Facility, in Recreation Areas), Washington D.C., 1964.

[4]Personal communication with staff of Boating Industries Association, 401 N. Michigan Avenue, Chicago Illinois 60611.

[5]Ontario Ministry of Natural Resources, Lakealert Phase 2: Methodology, Hough, Stansbury, and Associates, Ltd., Toronto, Ontario, 1972.

[6]Wisconsin Conservation Department, A Comprehensive Plan for Wisconsin, Outdoor Recreation, Madison, Wisconsin, 1966.

[7]Louisiana Parks and Recreation Commission, Louisiana Statewide Comprehensive Outdoor Recreation Plan, Supplement I, Baton Rouge. Louisiana, 1966.

[8]Chesapeake Bay Study; Demand, Supply, Needs, U. S. Department of the Interior, Bureau of Outdoor Recreation, Northeastern Regional Office, Philadelphia, Feb. 1974.

[9]California Public Outdoor Recreation Plan Committee, California Public Outdoor Recreation Plan, Sacramento, California, 1960.

[10]Placer County Recreation Commission, Proposed Public Outdoor Recreation Commission Plan: County of Placer, California, Auburn, California, 1963.

does not mean that all waterskiing becomes operationally impossible when boat densities reach a level of only 9 acres/boat, but rather, that at a density level which allows for fewer than 10 acres/boat, the satisfaction experienced by the boater will begin to be substantially reduced, to the point that a significant number of boaters may consider ending the day's activity, or moving to a less crowded area. In addition, the figure given as "normal" or "desirable" upper end of the surface area range indicates that at that point, most boaters will feel totally free in the exercise of their chosen activity, perceiving no pressure or conflict from other craft.

3. Navigational and External Conflicts

A number of conflicts exist among various types of recreational boating activity. These conflicts are caused to a large extent by the variety of speeds and operational characteristics associated with the different activities and by the physical characteristics of the water bodies on which they take place.

a. Speed/Safety: Primary among the conflicts are those caused by boaters operating their craft at different speeds within the same area. Speedboating and waterskiing activities require high speeds of operation and intricate course patterns which will conflict with fishing, cruising, and sailing activities over the same water surface. On the lower Chesapeake Bay, cruising speeds will usually range from 15 to 30 mph, waterskiing speeds will range in excess of 20-25 mph, and sailing speeds will be considerably less. The rules of navigation which give sail the right of way over power recognize the difference in maneuverability between the two types and thus to some extent alleviate this problem. However, as boating activities increase, the potential for collision and other accidents resulting from congestion and overcrowding of water bodies will increase.

In the vicinity of some harbors, speed limits have been established to reduce the conflict between moored craft and the wakes of passing boats. As mentioned in the introduction to this report, speed zones prohibiting speeds in excess of 6 knots have also been established for narrow channel areas where congestion or evidence of wake-induced shoreline erosion exist. Effective management of boating activities will necessitate that adequate criteria for determining the location of these zones be further developed to reduce the potential for future conflict.

Although some user conflicts are always present unless specifically regulated, others may occur at certain times. While the passing of a nearby speedboat will be upsetting to a slowly drifting angler, the fact that these activities are often carried out during different parts of the day tends to reduce the severity of that particular conflict. As indicated in the 1971 Coast Guard Study <u>A Recreational Boating Population Statistical Information System</u> (166), the major peak hours for motorboating and sailing activities appear to be relatively the same, around midday. However, the sailing activities are concentrated over a shorter time span, and there appears to be a significant early morning peak period for motorboats around 7:30. This peak probably represents a high percentage of motorboats being utilized for fishing activities, while the midday peak represents a higher intensity of waterskiing and cruising activities. In addition, as noted by the report, numbers of fishing boats will tend to exhibit seasonal variations due to the migratory patterns of fish inhabiting the area. Thus the degree of activity conflicts will vary greatly during the day and on a seasonal basis.

In addition to temporal separation, such as described above, incompatible types of boating activities will often tend to separate themselves. When available water surface allows, the powerboater is generally no more anxious to operate while surrounded by a fleet of sailboats than is the sailor to be in the midst of a group of powerboats. In light of the above, noticeable conflicts occur in areas where the overall levels of recreational boating reduces available surface area to the point where boating activity classes can no longer separate themselves adequately without travelling unreasonable distances, or in those areas which must be shared by different boating classes, such as the narrow reaches of rivers and creeks, and the approaches to multi-use marinas and harbors. It is in these areas that formalized temporal, spatial, and navigational regulations must be used to minimize use conflict types and levels.

b. Depth: The exercise of the varying forms of boating recreational activities are clearly affected by the depths of the waters in which the craft are being operated. According to the Outboard Motor Club of America, no precise required depth to boat size ratios exist. However, some general criteria can be stated. Most outboard powered boats require at least 3' of water for safe operation, and 4' is considered to be a desirable minimum. Around these figures, there is a range of required depths: manually powered craft and small sailboats can operate in less than 2', while many other craft, such as the very large sailboats and cruisers, may require up to 6' for safe operation. It should be noted that because shallow waters constitute a large portion of the waters used by Chesapeake Bay boaters, many boaters use craft which have been specifically designed with shallow draft hulls.

The depth patterns within a given area will serve to define the differential amount and configuration of the water surface which is available for the various types of boating activities. The hypothetical chart given below, Figure 3, illustrates how the percentage of total surface area available for boating activity will increase as the size of the water body increases. This results from the fact that shallow, unusable areas will constitute a larger percentage of the total surface areas of the small, highly indented coves and embayments of the bay region than of the larger open expanses of water.

c. Size and Openness of Water Body, Distance from Shore: From an operational perspective, the size and openness of the expanse of water over which boating activities occur will affect the amount of conflict between activities. Speedboating and waterskiing activities are more suitably carried out on long, wide river reaches, or at the outer limits of large embayments, areas which are not well suited for activities such as leisurely fishing or day sailing.

Similarly, sport fishing and long distance sailing and cruising are more suited to large open expanses of water.

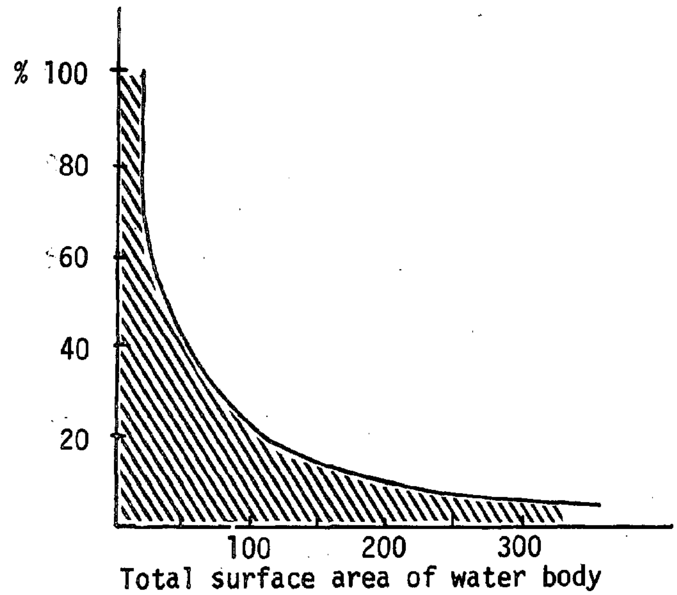


Figure 3: Surface Area Unavailable for Boating Activities

As far as distances from shore are concerned, the proximity to shore within which an activity will occur is primarily determined by the size of the boat being used. Rarely will motorboats and sailboats under 16' be utilized for activities outside of a one mile range. The 2-5 mile range is used by about 30% of motorboats over sixteen feet, while approximately 50% of sailboats over sixteen feet will be used in this range. Only 12% of motorboats over 16' and 23% of sailboats over 16' will venture beyond the five mile range (166). Thus, leisurely fishing, waterskiing, day cruising, and day sailing will constitute the activities usually enjoyed within close proximity to the shore, while sportfishing, long distance sailing, and long distance cruising will take place at greater distances from the shore.

d. Water Body Shoreline Configuration: The presence of complex branches and indentations off principal inlets and embayments will affect the usable water surface available for various boating activities. As an example, a narrow inlet with primary and secondary branches is more suited to activities such as leisurely fishing, and day sailing, than for speedboating or water-skiing. The shelter and visual interest offered by a multiple branched inlet makes for great attractiveness to the leisurely recreationist, while the shallowness and complexity make it difficult and unsafe for high speed operations.

SHORE ACCESS REQUIREMENTS AND FACILITIES

In addition to the boating operational and other factors discussed above, the design and location of boating facilities--marinas, launching ramps, piers, etc.--will affect the levels and patterns of boating activities in given areas. In terms of boating carrying capacity considerations, the primary impact of boating facility factors on boater satisfaction relates to the levels of congestion and convenience of access to boating activities. Since boating facility design constitutes a substantial portion of Part II of this report, boating facility factors are only briefly discussed below.

Facility Types

Generally, boating facilities can be classified into five categories: large marinas, small marinas, owners' association piers, individual owner's piers, and launching ramps.

Large Marinas will include facilities for storing boats (berths, moorings, dry storage); hoists, cranes or ramps for removing or lowering boats into the water; fueling and boat repair services; miscellaneous services such as restaurants, first aid and navigational information, sanitation and disposal facilities; and facilities related to automobile use--parking, gas, etc. In addition, charter boats or power boat rentals may be offered. These public or privately owned marinas (yacht and boat clubs) may contain storage facilities with enough space for two to four hundred boats or more.

Small marinas will include many of the facilities mentioned above on a smaller scale and will probably not contain extensive facilities for dry storage. Small sailing clubs and schools will often use these facilities.

Owners association piers are often small-scale docks or piers privately owned by groups of boaters with private access to the waterfront. These will usually not include fueling and repair services nor miscellaneous services such as food, rentals, etc.

Individual owners piers are those belonging to owners of waterfront property for the private storage of their boats. These facilities include the numerous finger piers and docks usually constructed on wooden pilings which fringe many of the shores of the Bays.

Launching ramps and service docks are predominantly state or locally owned and operated. They primarily provide facilities for boaters to launch trailered boats and to park their automobiles while out on the water. In some instances food, fuel, rentals, sanitation facilities, or other services may be offered.

Impact of Boating Facilities on Carrying Capacity

Many of the above facilities, particularly the larger marinas, will provide shelter in the form of breakwaters or other structures to protect boats being stored in the water from waves, boat traffic, tidal currents and winds. Channels may also be dredged to provide convenient access from the expanses of water to the more sheltered areas. In addition, water access to fueling and repair services, as well as to individual storage berths and dry storage loading docks will be provided.

The location and design of these facilities will affect the levels of boating congestion at their entrances on the water. Also, the types of facilities available will influence the type of boating activities which can utilize the storage and access points. Thus, their design and location can be an effective factor in balancing the distribution of boating activities and reducing congestion on the water.

Since a large percentage of boats in Maryland are trailered to these water access points, the location of these facilities can also significantly affect related land use problems such as traffic congestion and conflicts with other water-oriented forms of recreation. In the Chesapeake Bay area, for instance, the location of marinas should be determined with regard to the amount of generated boat traffic requiring the raising of drawbridges, in order to reduce boating and automobile traffic conflicts. Since there exists a rapid increase in the number of boats transported via trailer or car top to launching points and a steady increase in the number of water stored craft registered in Maryland, sufficient attention must be given in the future to the relation of boating facilities to boating carrying capacity criteria.

Summary

The above discussion has identified and classified the operational characteristics related to boating activities. In order to utilize this information in the boating capacity planning system presented in Chapter VI of this report, the R.M.A. study has developed generalized guidelines regarding the surface area requirements of boating activities. These guidelines are given in Table 4 below. These are preliminary standards for single-use boating activities carried out on a hypothetical water body which present no intangible, physiographic or ecological constraints. (Subsequent chapters of this report detail the effect of various intangible and ecological constraints on boating activities.) For the sake of analysis, the "normal" standard refers to the amount of surface area considered desirable for the exercise of the particular activity: more area is welcome, less area begins to define congestion. Similarly, the "minimum" standard refers to the point at which a significant number of boaters will begin to perceive an unacceptable level of congestion and may decide to remove themselves from the area.

Table 4

Derived Carrying Capacity Standards (acres/boat)

Activity	Normal	Minimum	Activity	Normal	Minimum
Speedboating	10	5	Day Cruising	10	3
Waterskiing	20	10	Long Distance Cruising	10	5
Sportfishing	10	3	Day Sailing	3	1.5
Leisurely Fishing	5	1	Long Distance Sailing	5	2

Speedboating--the range of 5 to 10 acres/boat reflects the higher maneuverability of the speedboat as opposed to a similar boat pulling a skier; being more mobile, the speedboater is less apt to feel himself being pressured by meandering boaters.

Waterskiing--The carrying capacity criteria of 10 to 20 acres is perhaps the closest thing to an official standard, having been verified in several field test situations. Given the greatly exaggerated length of the boat/skier combination, together with decreased maneuverability, this activity emerges as having the greatest demand for water surface.

Sportfishing--The sportfisherman prefers an uncrowded area in which to pursue the "big one that got away". Otherwise the activity tends to exhibit surface area requirements similar to those of the powered cruisers.

Leisurely fishing--Operating quietly at very slow speeds, the casual angler prefers "privacy" when it is available, but can tolerate higher densities when necessary.

Cruising--Day cruising reflects the surface needs of powerboats, as outlined in the current literature, namely, from 3 to 10 acres per boat. With respect to long distance cruising, the minimum standard was revised to 5 acres/boat to reflect more of a dissatisfaction with crowded conditions on behalf of the boater.

Sailing--Discussions with organizations and individuals active in sailing, together with the review of available literature, led to the adoption of a range from 1.5 to 3 acres/boat as the carrying capacity standard for day sailing, the most common form of sailing. For reasons similar to that discussed above under cruising, the spatial need of long distance sailing has also been revised upward, to reflect the desire for free and unfettered operation on the part of the long distance sailor.

The chart below, Figure 4, provides an illustration of how some of the carrying capacity standards compare, relative to each other. From the chart it is evident that waterskiing activities exhibit the greatest demand for water surface area, while day sailing and leisurely fishing activities require less surface area to provide desirable levels of boater satisfaction.

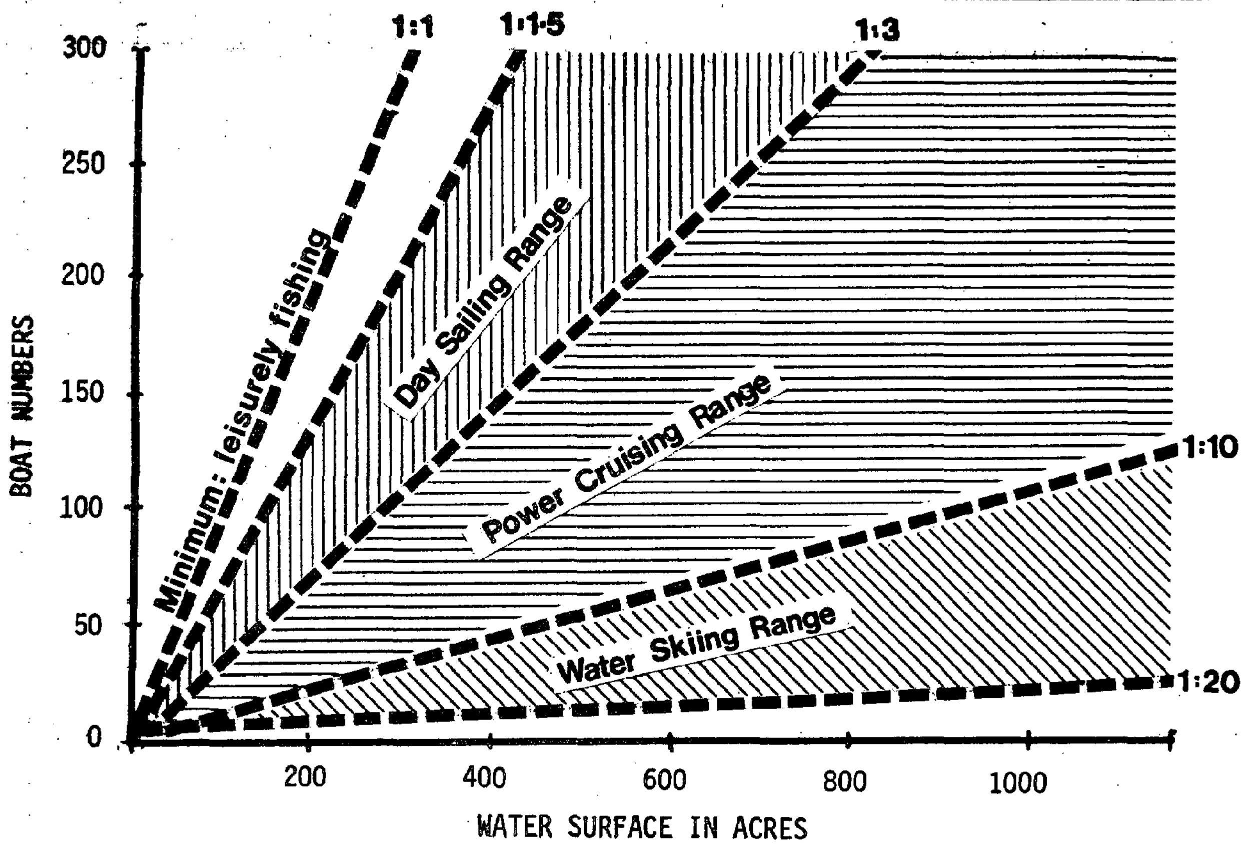


Figure 4: Comparison of Carrying Capacity Standards

The carrying capacity standards presented in Table were derived only for single use boating activities over a defined area. Obviously the assumption that only one type of boating activity will occur in a specific area over time is unrealistic. However, the complex task of attempting to develop carrying capacity standards for combinations of the various activities would provide results too cumbersome to be of useful value for planning purposes. At any rate, the figures below have been prepared to illustrate hypothetically how the carrying capacity standards as they were derived can be applied to a fixed surface area.

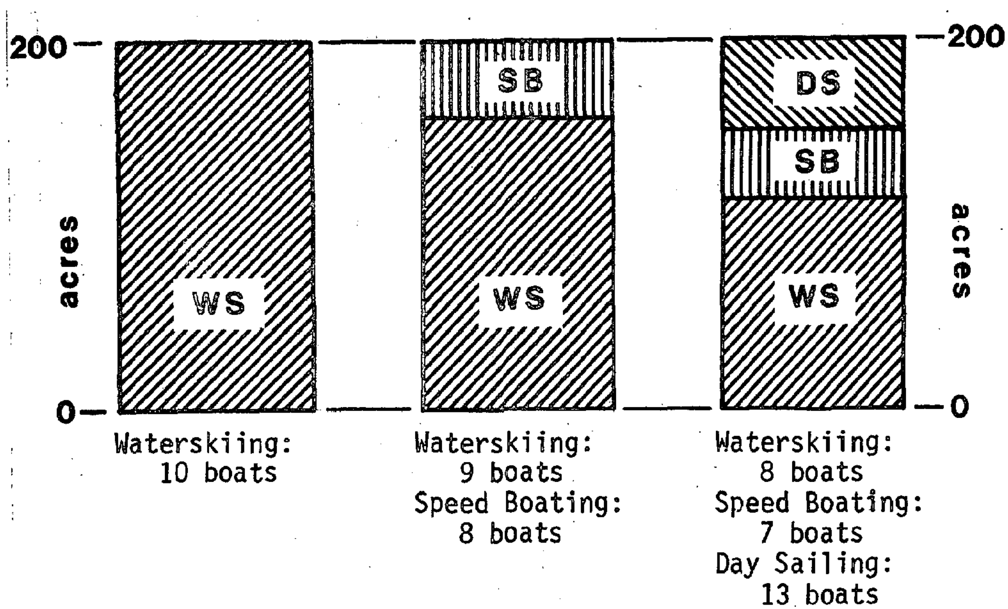


Figure 5: Effect of Mixed Usage on Boating Capacity

The above graphs illustrate how mixing of competing uses affects user satisfactions and numbers within a fixed acreage of surface.

The users of these carrying capacity standards must recognize that they represent only initial estimates of surface area requirements associated with boating activities. Their utility as a planning tool will depend on the degree to which they are validated, revised, and continually updated through monitoring of observed actual conditions. In addition, there will be temporal variations around the norms as both seasonal and daily fluctuations in peak boating activity demand occur. However, Chubb (195) suggests that it may be advisable to use carrying capacity standards which relate to the ability of a particular area to sustain continuous use over an entire season. The assessment of existing and projected boating activity demand in the Chesapeake and Chincoteague Bay regions which will be undertaken in Phase II of this research will be utilized to refine these figures to ensure that they accurately reflect actual conditions.

CHAPTER IV

USE CONFLICTS
VISUAL AND INTANGIBLE CONSIDERATIONS

INTRODUCTION

From the perspective of boater satisfaction, the boating operational and facility requirements outlined in the previous chapter were considered to be the primary determinants of boating carrying capacity standards. However, the degree to which the spatial characteristics of actual boating activities on the Chesapeake and Chincoteage Bays will correlate with these preliminary standards will also depend on the influence of several considerations. These considerations have been generally grouped into two categories - Use Conflicts and Visual and Intangible Considerations - and are discussed in the sections below.

USE CONFLICTS

Recreational boating activities may often conflict with other man-oriented uses of the aquatic environment. In the case of the Chesapeake Bay region, other uses which may potentially conflict with boating activities are commercial shipping, commercial fishing, vehicular transportation, private shore front property use, and other shore oriented recreational pursuits such as swimming and fishing.

1) Commercial shipping

While the actual shoreland facilities - cargo storage, loading docks, etc. - associated with commercial shipping consume only a fraction of the total land area bordering the bay, the necessity for deep draft shipping channels and special facilities such as the Chesapeake and Delaware Canal deserve particular consideration in planning boating recreational activities. The large tankers, freighter, and passenger lines traversing shipping channels have limited maneuverability and, thus, pose navigational hazards for small craft. In addition, the location of naval anchorages and commercial harbors as well as the shipping channels should be considered in evaluating the location and level of boating activities. The locations of commercial shipping channels and moorings are well marked on available maps and will be considered in Part 11 of this study.

2) Commercial Fishing

An important component of the economic activity of the Bay region is the commercial fishing industry. This industry includes commercial crabbing, clamming, and oyster harvesting as well as the netting of fin fish. There are approximately 10,000 commercially licensed oysterboats and clamboats in the state of Maryland. Boundaries prohibiting upstream or shoreward harvesting of the various species have been set at many of the river mouths and headlands of bays, coves and inlets. Power recreational boating activities should be regulated in shellfish and fish spawning areas during critical seasonal stages where monitoring and surveillance reveal probable boating impacts.

3) Vehicular Transportation

As a result of the large number of drawbridge crossings in the bay area, the effect of increased boat traffic on vehicular traffic flows must be considered. Also, the location of launching ramps, marinas, and other facilities can significantly influence the utilization of access roads and highways leading to the water's edge. Likewise, the ease with which boaters can get to water access points will determine where concentrations of boating activities will occur. Each of these factors should be carefully considered.

4) Shore Frontage Property Use

In order to prevent shoreline erosion of their property resulting from the impact of boat wakes in narrow channels or passageways, shorefront property owners will often construct bulkheads or other coastal protection devices. They may also petition the marine police to establish speed zones restricting powerboating and waterskiing activities where noise levels or other factors cause excessive disturbances. Thus, it is important that the uses of privately owned lands along the shoreline be considered in planning boating recreational activities, since the establishment of speed zones, buffer zones, or other restrictions will limit the water surface area available for boating.

5) Other Recreation

Besides boating activity, other recreational pursuits, particularly swimming and fishing from or near the shore, compete for use of inshore waters. Most swimming activity at beaches and suitable shores will be concentrated shoreward of the 5' depth contour and may extend outward to the 10' contour. (Threinen, 1964) Maryland DNR regulations presently exclude water-skiing within 100 feet of swimmers, shores piers, and other appurtenances. Consideration should be given to extending the regulations to prohibit speeds greater than a tolerable maximum (to be determined) for all powerboat use within inshore zones with designated fishing, swimming or similar activity priorities.

VISUAL AND INTANGIBLE CONSIDERATIONS

Boats of all types and most boating facilities possess aesthetic attributes of great interest and value to the boating, as well as to the non-boating public. Some aspects of boating facilities and activities, however, encompass actual or potential incompatabilities with the landscape, waterscape, or use-environment within which they are found.

1) Wake

In addition to the potential shoreline disturbance effects described earlier, the occurrence of high wake which interferes with the recreational enjoyment of others, jars moored craft, or creates hazards, can be considered an adverse aesthetic factor.

2) Fuel Exhausts

Although most power boat users and many sailors are accustomed to escaped engine exhausts, some may be presumed to feel that concentrations of exhaust fumes are aesthetically undesirable. If engine modifications were to be made to reduce the amount of unburned and partially consumed fuel in engine exhausts, for reasons of ecological protection, the aesthetic environment would be enhanced as well.

3) Noise

Besides wake, engine noise is the chief aesthetic irritant of powerboat operation to non-powerboat users. Although little research appears to have been done into the tolerances of users to engine noise, it has been commonly observed that a number of engine makes have insufficient muffling in relation to horsepower. This is particularly true of certain outboard and outboard-inboard power systems.

Under present MDNR regulations, complaints by frontage property owners may lead to the issuance of citations for excessive engine noise. However the origin of the problem lies with engine design and ways to encourage or to require manufacturers to improve muffling characteristics should be explored.

4) Facility displacement of valuable natural environment

The construction of marinas and launching ramps on filled salt marshes and scenic shorelines proclaims a status of misuse and degradation of socially valuable resources. The scarring of bluffs by access road or facility construction may also be considered aesthetically significant. In addition to this intangible effect, visual impacts will also be obvious at damaged remnants of marshes adjacent to the facility and disharmony or discontinuity between the natural and built area will be apparent.

The appearance and design of some marinas, whether built on suitable or unsuitable shorelines may also fail in terms of architectural merit, site layout, or the characteristics of repair yards, dry storage, hoists, sheds, and other features. Critical to the question of appearance is the design of elements at the land edges of the facility, particularly those which abut residential or scenic areas.

Appearance and design questions will be treated in depth in Part Two of this report.

INTRODUCTION

The material presented in this chapter is provided to explain the relationships between boating operational and facility factors and the components of the aquatic environments of Chesapeake and Chincoteague Bays.

The Bio-Physical Checklist, Table 5, is intended to provide a quick reference source for the user to gain a comprehensive view of how boating operational and facility causative factors may potentially produce subsequent responses in the bay ecosystems.

The Key to the Bio-Physical Checklist, Table 6, and its attendant verbal analysis is provided to facilitate the "tracing through" of the relationships presented in the preceding flow chart form of the Bio-Physical Checklist. The verbal analysis explains how causative factors related to boating activities may induce adverse responses in the aquatic envoronment.

The matrix, Table 7, presented at the conclusion to this section depicts the relative significance of these responses.

The final section of this chapter summarizes the environmental constraints to be considered in planning future boating activity for Chesapeake and Chincoteague Bays.

The content of this chapter is based primarily on a literature search of the pertinent available material and verbal communication with various experts conducting research in the field. In many cases there are conflicting views or inconclusive results regarding the impact on the aquatic environment caused by boating operational and facility factors.

It is probably true that relative to the other factors affecting the overall environmental quality of the bay (e.g. oil spillage from commercial shipping), boating related impacts have very little significance. However, where boating activity is highly concentrated near the shore or near marina or launching ramp facilities, localized effects may be quite significant. In addition, as the numbers of recreational boaters using the waters of the bay continue to rise, the amount of environmental degradation caused by boating realted activities may become more severe. At any rate, relevant research should be continually analyzed and the material presented in the following sections should be continually updated to reflect any conclusive findings.

THE BIO-PHYSICAL CHECKLIST

The Bio-Physical Checklist on the following page portrays the general relationships between boating activity and facility construction on the one hand and the estuarine elements typical of Chesapeake and Chincoteague Bays on the other. Causative factors associated with boating activity and the construction and operation of short support facilities are arrayed in terms of their potential immediate effects on the environment, the subsequent changes in environmental factors, the biological responses which occur, and finally, the eventual ecosystem response.

CHAPTER V

RECREATIONAL BOATING
BIO-PHYSICAL IMPACT ANALYSIS

KEY TO THE BIO-PHYSICAL CHECKLIST

The key accompanying the bio-physical checklist was developed to aid in tracing the relationships presented in the flow chart format. It does not attempt to quantify or to rank identified impacts, but rather to clarify the process of "tracing through" the effects of boating-related causative factors. Relationships between causative factors, immediate effects, changes in environmental factors, biological responses, and subsequent ecosystem responses are explained in the text immediately following the key.

Table 6

Note: Factors below have been checklisted without distinction as to relative impact significance. Refer to the text: Environmental Responses, for a discussion of relative impact significance.

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilative Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
A Boating Operations									
B PROPELLER CUTTING									
C Destruction of Aquatic Vegetation									
1. decreased photosynthesis and primary productivity					○			◐	
2. accumulation of organic debris on bottom: altered substrate			○						
3. increased breakdown of organic matter: decreased dissolved oxygen concentrations			○			○	◐	◐	
B BOAT WAKE									
C Sediment Resuspension									
1. release of toxins and noxious gasses: accumulation of toxins by organisms				◐					
2. flocculation and precipitation of planktonic algae: decreased photosynthesis and primary productivity					●			●	
3. disruption of bottom sediments: altered substrate			◐						
4. disruption of bottom dwellers								●	
5. increased turbidity: decreased light penetration - decreased photosynthesis and primary productivity					●				
6. increased turbidity: decreased light penetration - impairment of sightfeeders	●							●	
7. increased turbidity: fish gill inflamation		●						●	
8. increased turbidity: closing of mussels		●						●	
9. increased turbidity: reduced pumping of oysters		●						●	
10. increased turbidity: interference with filterfeeders	●							●	

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilative Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
C Erosion									
1. increased turbidity: decreased light penetration - decreased photosynthesis and primary productivity					O				
2. increased turbidity: decreased light penetration - impairment of sightfeeders	O							O	
3. increased turbidity: fish gill inflamation		O						O	
4. increased turbidity: closing of mussels		O						O	
5. increased turbidity: reduced pumping of oysters		O						O	
6. increased turbidity: interference with filterfeeders	O							O	
7. increased sedimentation: smothering of bivalves, other bottom dwellers								O	
8. increased sedimentation: altered substrate			O						
B PROPELLER WASH									
C Sediment Resuspension									
1. release of toxins and noxious gasses: accumulation of toxins by organisms				O					
2. flocculation and precipitation of planktonic algae: decreased photosynthesis and primary productivity					O			O	
3. disruption of bottom sediments: altered substrate			O						
4. disruption of bottom dwellers								O	
5. increased turbidity: decreased light penetration - decreased photosynthesis and primary productivity					O				
6. increased turbidity: decreased light penetration - impairment of sightfeeders	●							●	
7. increased turbidity: fish gill inflamation		●						●	
8. increased turbidity: closing of mussels		●						●	

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilation Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
9. increased turbidity: reduced pumping of oysters		○						●	
10. increased turbidity: interference with filterfeeders	○							●	
B NOISE									
C Disturbance of Wildlife									
1. abandonment of feeding and nesting grounds	●	○						●	
B RELEASE OF SANITARY WASTES AND GARBAGE									
C Introduction of bacteria									
1. accumulation of bacteria in organisms				○					●
C Increase in organic matter									
1. increased breakdown of organic matter: decreased dissolved oxygen concentrations			●			●	●	●	
2. accumulation of organic debris on bottom: altered substrate			●						
B ANTI-FOULING TOXINS									
C Leaching of toxic substances into water									
1. accumulation of toxins in organisms				●					
B OIL AND GAS SPILLAGE									
C Introduction of toxins									
1. incorporation of toxins by organisms	●	●		●				●	●
2. tainting of filterfeeders (especially bivalves) and some fish (especially mullet)	●	●							●
3. incorporation of oil into sediments: altered substrate			●						
4. incorporation of oil into sediments: accumulation in detrital matter and in detritus feeders	●	●		●				●	

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilative Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
C Flotable scum on water's surface									
1. flocculation and precipitation of suspended materials, adsorption on particles			●						
2. coating of organisms: interference with feeding and respiration of molluscs, crustaceans, and bivalves	●	●						●	
3. coating of organisms: decrease in photosynthesis of algae and rooted aquatics					●			●	
4. coating of organisms: disruption of insulation and buoyancy of diving birds	●	●						●	
5. reduced light penetration: decreased photosynthesis and primary productivity					●				
6. blocked airborne oxygenation of water: decreased dissolved oxygen concentrations			●			●			
B EMISSION OF EXHAUST FUMES									
C Increased hydrocarbons in air: effects not fully known									
C Introduction of hydrocarbons into water									
1. incorporation of toxins by organisms	●	●	●					●	●
2. tainting of filterfeeders (especially bivalves) and some fish (especially mullet)	●	●							●
3. incorporation of oil into sediments: altered substrate			●						
4. incorporation of oil into sediments: accumulation in detrital matter and in detritus feeders	●	●		●				●	
A On-Shore Facilities									
B CONSTRUCTION OF FACILITIES									
C Dredging									
1. alteration of the substrate			●						
2. disruption of bottom dwellers								●	

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilative Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
3. elimination of vegetation: decreased photosynthesis and primary productivity					○			◐	
4. increased turbidity: decreased light penetration - decreased photosynthesis and primary productivity					○				
5. increased turbidity: decreased light penetration - impairment of sightfeeders	○							◐	
6. increased turbidity: fish gill inflamation		○						◐	
7. increased turbidity: closing of mussels		○						◐	
8. increased turbidity: reduced pumping of oysters		○						○	
9. increased turbidity: interference with filterfeeders	◐							◐	
10. sediment resuspension: release of toxins and noxious gasses - accumulation of toxins in organisms				◐					
11. sediment resuspension: flocculation and precipitation of planktonic algae - decreased photosynthesis and primary productivity					◐			●	
12. change in water circulation patterns			○			○		●	
C Filling and Spoil Disposal									
1. elimination of vegetation: decreased photosynthesis and primary productivity					○			◐	
2. release of toxic substances: accumulation of toxins in organisms				◐					
3. alteration of the substrate			○						
4. restriction of water movement: retention of pollutants - decreased dissolved oxygen concentrations			○			◐	◐	◐	
5. restriction of water movement: reduced oxygenation - decreased dissolved oxygen concentrations			●			●		●	

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilative Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
6. restriction of water movement: changed salinity			●					●	
7. restriction of water movement: increased water temperature - decreased dissolved oxygen concentrations			●			●		●	
8. smothering of bottom dwellers								●	
C On-Shore Construction									
1. erosion: turbidity - decreased light penetration, decreased photosynthesis and primary productivity					◐				
2. erosion: turbidity - decreased light penetration, impairment of sightfeeders	◐							◐	
3. erosion: turbidity - fish gill inflamation		◐						◐	
4. erosion: turbidity - closing of mussels		◐						◐	
5. erosion: turbidity - reduced pumping of oysters		◐						◐	
6. erosion: turbidity - interference with filterfeeders	○							○	
7. erosion: sedimentation - smothering of bivalves, other bottom dwellers								○	
8. erosion: sedimentation - alteration of substrate			○						
9. elimination of vegetation: decreased photosynthesis and primary productivity					○			○	
B CHANNELS AND CHANNEL ALTERATIONS									
C Reduced flushing and mixing of waters									
1. retention of pollutants: decreased dissolved oxygen concentrations			○			○	○	○	
2. reduced oxygenation of waters: decreased dissolved oxygen concentrations			○			○		○	
3. changed salinity			◐					◐	
4. increased water temperature: decreased dissolved oxygen concentrations			◐			◐		◐	

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilation Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
5. precipitation of blanket of sludge: altered substrate			O					O	
C Change in freshwater flows									
1. reduced salinity: reduced dissolved oxygen saturation limit			O			O		O	
2. creation of salinity barrier to anadromous fish migration		O	O					O	
C Periodic Dredging									
1. alteration of substrate			O						
2. elimination of vegetation: decreased photosynthesis and primary productivity					O			O	
3. disruption of bottom dwellers								O	
4. increased turbidity: decreased light penetration - decreased photosynthesis and primary productivity					O				
5. increased turbidity: decreased light penetration - impairment of sightfeeders	O							O	
6. increased turbidity: fish gill inflamation		O						O	
7. increased turbidity: closing of mussels		O						O	
8. increased turbidity: reduced pumping of oysters		O						O	
9. increased turbidity: interference with filterfeeders	O							O	
10. sediment resuspension: release of toxins and noxious gasses - accumulation of toxins in organisms				O					
11. sediment resuspension: flocculation and precipitation of planktonic algae - decreased photosynthesis and primary productivity					O			●	
12. change in water circulation patterns			O			O		●	
C Associated Spoil Disposal									
1. elimination of vegetation: decreased photosynthesis and primary productivity					O			●	

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilative Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
2. release of toxic substances: accumulation of toxins in organisms				●					
3. alteration of substrate			●						
4. restriction of water movement: retention of pollutants - decreased dissolved oxygen concentrations			●			●	●	●	
5. restriction of water movement: reduced oxygenation - decreased dissolved oxygen concentrations			●			●		●	
6. restriction of water movement: changed salinity			●					●	
7. restriction of water movement: increased water temperature - decreased dissolved oxygen concentrations			●			●		●	
8. smothering of bottom dwellers								●	
C Increased sedimentation									
1. smothering of bivalves, other bottom dwellers								●	
2. altered substrate			●						
B BREAKWATERS									
C Reduced flushing and mixing of waters									
1. retention of pollutants: decreased dissolved oxygen concentrations			●			●	●	●	
2. reduced oxygenation of waters: decreased dissolved oxygen concentrations			●			●		●	
3. changed salinity			●					●	
4. increased water temperature: decreased dissolved oxygen concentrations			●			●		●	
5. precipitation of blanket of sludge: altered substrate			●					●	
C Increased sedimentation									
1. smothering of bivalves, other bottom dwellers								●	

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilative Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
2. altered substrate			O						
B DOCKS, PIERS, AND RAMPS: SERVICE, LAUNCHING									
C Reduced flushing and mixing of waters									
1. retention of pollutants: decreased dissolved oxygen concentrations			O			O	O	O	
2. reduced oxygenation of waters: decreased dissolved oxygen concentrations			O			O		O	
3. changed salinity			O					O	
4. increased water temperatures: decreased dissolved oxygen concentrations			O			O		O	
5. precipitation of blanket of sludge: altered substrate			O					◐	
C Increased sedimentation									
1. smothering of bivalves, other bottom dwellers								◐	
2. altered substrate			◐						
C Leaching of toxins from anti-fouling paints									
1. accumulation of toxins in organisms				O					
C Introduction of Sewage, Garbage, Debris									
1. introduction of bacteria: accumulation of bacteria in organisms				◐					◐
2. increased breakdown of organic matter: decreased dissolved oxygen concentrations			◐			◐	◐	◐	
3. accumulation of debris on bottom: altered substrate			◐						
C Gas and Oil Slicks and Spills									
1. incorporation of toxins by organisms	◐	◐		◐				●	●
2. tainting of filterfeeders (especially bivalves) and some fish (especially mullet)	◐	◐							●
3. incorporation of oil into sediments: altered substrate			●						
4. incorporation of oil into sediments: accumulation in detritus and detritus feeders	●	●		●				●	

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilative Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
5. flocculation and precipitation of suspended materials, adsorption on particles			●						
6. coating of organisms: interference with feeding and respiration of molluscs, crustaceans, and bivalves	●	●						●	
7. coating of organisms: decrease in photosynthesis of algae and rooted aquatics					●			●	
8. coating of organisms: disruption of insulation and buoyancy of diving birds	●	●						●	
9. reduced light penetration: decreased photosynthesis and primary productivity					●				
10. blocked airborne oxygenation of water: decreased dissolved oxygen concentrations			●			●			
C Increased freshwater flow into estuary									
1. reduced salinity: reduced dissolved oxygen saturation limit			●			●		●	
B SLIPS AND BERTHS (MARINAS), ASSOCIATED SERVICES									
C Reduced flushing and mixing of waters									
1. retention of pollutants: decreased dissolved oxygen concentrations			●			●	●	●	
2. reduced oxygenation of waters: decreased dissolved oxygen concentrations			●			●		●	
3. changed salinity			●					●	
4. increased water temperature: decreased dissolved oxygen concentrations			●			●		●	
5. precipitation of blanket of sludge: altered substrate			●					●	
C Increased sedimentation									
1. smothering of bivalves, other bottom dwellers								●	
2. altered substrate			●						
C Leaching of toxins from anti-fouling paints									
1. accumulation of toxins in organisms				●					

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilative Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
C Gas and Oil Slicks and Spills									
1. incorporation of toxins by organisms	○	○		○				○	◐
2. tainting of filterfeeders (especially bivalves) and some fish (especially mullet)	◐	○							◐
3. incorporation of oil into sediments: altered substrate			○						
4. incorporation of oil into sediments: accumulation in detrital matter and in detritus feeders	◐	◐		○				◐	
5. flocculation and precipitation of suspended materials, adsorption on particles			○						
6. coating of organisms: interference with feeding and respiration of molluscs, crustaceans, and bivalves	◐	◐						◐	
7. coating of organisms: decrease in photosynthesis of algae and rooted aquatics					◐			◐	
8. coating of organisms: disruption of insulation and buoyancy of diving birds	◐	◐						◐	
9. reduced light penetration: decreased photosynthesis and primary productivity					◐				
10. blocked airborne oxygenation of water: decreased dissolved oxygen concentrations			◐			◐			
C Introduction of Sewage, Garbage, Debris									
1. introduction of bacteria: accumulation of bacteria in organisms				◐					●
2. increased breakdown of organic matter: decreased dissolved oxygen concentrations			●			●	●	●	
3. accumulation of debris on bottom: altered substrate			●						
B NAVIGATIONAL AIDS									
C Disturbance of wildlife									
1. abandonment of feeding and nesting grounds	●	●						●	

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilative Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
B ACCESS TO ON-SHORE FACILITIES (ROADS, PARKING)									
C Increased freshwater flow into estuary									
1. reduced salinity: reduced dissolved oxygen saturation limit			●			●		●	
C Disturbance of wildlife									
1. abandonment of feeding and nesting grounds	●	●						●	
C Sheet and gully erosion									
1. increased turbidity: decreased light penetration - decreased photosynthesis and primary productivity					●				
2. increased turbidity: decreased light penetration - impairment of sightfeeders	●							●	
3. increased turbidity: fish gill inflamation		●						●	
4. increased turbidity: closing of mussels		●						●	
5. increased turbidity: reduced pumping of oysters		●						●	
6. increased turbidity: interference with filterfeeders	●							●	
7. increased sedimentation: smothering of bivalves, other bottom dwellers								●	
8. increased sedimentation: alteration of substrate			●						
C Trampling and Destruction of Shore Vegetation									
1. reduced photosynthesis and primary productivity					●			●	
2. erosion: turbidity - decreased light penetration, decreased photosynthesis and primary productivity					●				
3. erosion: turbidity - decreased light penetration, impairment of sightfeeders	●							●	
4. erosion: turbidity - fish gill inflamation		●						●	
5. erosion: turbidity - closing of mussels		●						●	
6. erosion: turbidity - reduced pumping of oysters		●						●	

Key to Bio-Physical Checklist

	Change in Growth Rates	Behavioral and Reproductive Changes	Habitat Alteration	Concentration and Magnification of Toxins in Food Chain	Decreased Estuarine Productivity	Reduced Assimilative Capacity	Eutrophic Conditions	Change in Number of Individuals and in Species Composition	Human Health Hazard
7. erosion: turbidity - interference with filterfeeders	●							●	
8. erosion: sedimentation - smothering of bivalves, other bottom dwellers								●	
9. erosion: sedimentation - alteration of substrate			●						

PHYSICAL IMPACTS

Propeller Cutting

The effects of propeller cutting are discussed by Clark and Niering (239, 240). If power boats are used in shallow areas, destruction of rooted aquatics by propeller action may occur. Zieman reports preliminary analyses of experiments undertaken in the Florida Everglades indicate that rooted aquatics may be severely depleted by prop cutting, depending on the regenerative characteristics of the species and the intensity of power boat activity.* The species composition of the estuary may also be narrowed through a decrease in the available herbivore food supply and through destruction of the habitat of various marine organisms (199, 239, 240). The plant debris, if it accumulates on the bottom may alter the substrate and consequently the habitats of indigenous organisms. Dissolved oxygen concentrations may decrease as the result of bacterial action in breaking down the increased amount of organic matter (239, 208). Habitat conditions may be altered, and eventually species composition changed. Eutrophication may be speeded up as the ability of the water body to assimilate wastes is reduced.

If washed up on marsh fringes, large amounts of propeller cuttings could interfere with living vegetation and cause a further decrease, albeit a probably insignificant one, in primary productivity, as well as alteration of the marsh edge habitat during the growing season (240).

The effects of propeller action depicted above, however, are probably rarely significant, inasmuch as they will be highly localized. In addition,

* Work in progress, Department of Environmental Science, University of Virginia, personal communication.

boaters will tend to avoid shallow areas colonized by rooted aquatics because of the potential for fouling of their propellers by the vegetation.

Boat Wake

The principal impact of boat wakes is an increase in localized turbidity, caused by the resuspension of bottom sediments and any induced shore erosion. Clark and Niering discuss the relationships in the appendices to this report. Hollis, Boone, DeRose, and Murphy (103) document the harmful effects of turbidity on fish growth and reproduction. Anderson (100) has done work on the impact of boat waves in New England tidal flats. Das (101) studied wave characteristics of a cargo ship and a pleasure cruiser, moving at various speeds and in different depths of water, to determine peak wave energies and effects on erosion, moored vessels, and docks. In that study, the speed of the craft was found to be a very important parameter.

The wave energy present in boat wakes and the turbulence resulting from the movement of boats in the water stirs up the unconsolidated sediments of estuary bottoms, which can alter the substrate and the habitat of benthic organisms, and increase ambient turbidity levels (239, 240). Toxins and obnoxious gases may be released when the sediments are disrupted and may accumulate in the tissues of marine organisms (239, 119). The increased particulate matter in the water may also result in the flocculation and precipitation of planktonic algae (103, 106) which would cause a decrease in primary productivity, since, as the base of the food chain, they play a vital role in the maintenance of estuarine productivity. Primary productivity can be further reduced by the reduction in light penetration caused by increased turbidity (239,240,119). Sight feeders may be hindered by the reduced light. Particulate matter can affect not only algae, but mussels, oysters and other filter feeders, and fish must adapt to these conditions (103). Changes in growth rates, behavioral and reproductive patterns, and conceivably, in their numbers can be expected, depending on impact severity.

In narrow water bodies or waterways, the impact of boat wake on the shoreline is likely to cause erosion (240). Depending on whether the existing rate of erosion in an area is initially high or low, the impact from boat wake may accelerate the natural process of erosion or have relatively minor effect. A high erosion rate is considered to be a loss of more than 0.2 acres of shore per mile per year (22). Where erosion is already rapid, the impact of the wake generated by high speed cruising or waterskiing can be high; wake caused by fishing, sailing, and other low speed activities will not cause any significant erosion of the shore.

Prop Wash

The turbulence resulting from the action of propellers, referred to as "prop wash", may also be responsible for the resuspension of unconsolidated bottom sediments. The problem is especially severe when the bottom sediments are fine, since small particles are more readily resuspended (103).

The actual physical disruption of benthic organisms (amphipods, annelids, crabs and shellfish) can be an immediate effect, but in addition, the suspended particles can smother bivalves and interfere with filter feeders (240). Yousef (107) concludes that resuspension of solids from the bottom and aquatic macrophytes can result from boating activity, particularly in shallow areas of less than 5' in depth. The increase in turbidity was generally accompanied by increases in organic carbon and phosphorus concentrations. However, he notes the necessity for further research to determine the significance of these effects.

In areas of bottom sediments of fine particle size, boat wake and propeller wash from boats engaged in cruising or waterskiing may have a relatively high impact in terms of sediment resuspension. The higher speed ranges generally associated with these activities will produce more severe impacts than the wake and wash generated by fishing,wwhich does not require high speeds or constant movement. In addition, skiing, since it occurs nearer shore (where water is shallower and sediments are nearer the surface) a greater percentage of the time, will probably produce more sediment resuspension than other boating activities. If bottom sediments are coarse, however, the likelihood of severe sediment resuspension by any boating activities is minimal.

Noise

Although the technical appendices do not mention the effects of noise from power boat operations, Sorenson does cite noise as being disruptive to wildlife often resulting in an alteration of behavior patterns and possibly in abondonment of habitat. However, there is no further discussion of the severity of this impact. Studies are needed to determine how often wildlife disturbance is directly dependent on noise; whether or not wildlife adapt to certain noise levels; what levels of noise will seriously impair the functioning of organisms. In some respects, airport noise studies may be useful in spite of the differences in decibel levels and other conditions.

The recreational boat noise problem is recognized in a study by Magrab (104). Taking measurements of noise from boats with various sizes of motors, he found that most motors emit an unacceptable level of noise to people in the vicinity of boating operations. He does not consider wildlife; instead, he assesses the impact of noise on other recreationists and boat operators: noise can be a safety hazard in times of limited visibility when aural signals are essential, as well as cause permanent hearing damage to individuals.

Dredging

Dredging, an activity closely associated with the construction and maintenance of channels and marina facilities, is discussed in some detail in the technical appendices of this report. The removal of materials from the bottoms of estuaries to increase water depth and facilitate ship or boat handling may have a high impact on the estuarine environment, which can be further intensified by the general frequency and widespread nature of this practice.

The immediate effect of dredging is obviously an alteration of the substrate. Benthic fauna and rooted vegetation are also removed when bottom material is removed (167,234,119). Thus habitat is destroyed, primary producers are eliminated, and the population of benthic fauna is reduced. These changes, depending on the extent of dredging activities, may in turn alter the species composition of the area through the reduction of the available food supply. Fish and other organisms higher in the food chain may emigrate in search of food and may suffer changes in growth rates, behavior, and reproductive patterns. If the reduction in population densities is sufficiently severe, certain species may be eliminated (119).

Aside from the material removed, the process itself causes sediment resuspension and increased turbidity. As discussed previously, trace metals, toxic substances, and obnoxious gases may be released when bottom sediments are disrupted and may be concentrated in organisms, or they may be incorporated into bottom materials again (92).

Flocculation and precipitation of algae may be another result (103). Turbidity reduces light penetration and photosynthesis, again possibly affecting primary productivity. Also, if nutrients are released, the increased nutrient availability could stimulate algae blooms, hastening the eutrophication process (119). The suspended particles may also interfere with the normal activities of marine animals, as described in the siltation and turbidity literature review(103).

On the other hand, the action of suspended clay particles in "scrubbing" or adsorbing toxins, metals, and other contaminants may constitute a beneficial effect, according to Gustafson (102).

By deepening water basins and channels, dredging alters water circulation patterns. This can be a major causative factor in that water circulation affects so many habitat suitability parameters. Clark points out that nutrient and pollutant concentrations and retention times, salinity, mixing, sedimentation, and shore erosion are all affected when circulation patterns change. The impact is inversely proportional th the size of the water body and the flushing rate; in other words, the larger the water body and the greater the flushing rate, the milder the impact of a change in circulation. The concepts of "contamination potential" and "turbidity potential" are useful in attempting to predict the impact which a change in circulation will have on a specific water body (239).

In general, decreases in circulation are detrimental to water body ecosystems, especially if they are receiving high inputs of pollutants and nutrients, since contaminants are not as readily flushed from the system (239). Decreased water movement usually decreases the dissolved oxygen content by reducing oxygenation; water temperature usually rises, which means that less oxygen can be dissolved in the water. Reduction in dissolved oxygen concentrations limits the ability of the water body to assimilate wastes, and leads to the creation of anaerobic conditions. Changes in species composition will parallel these habitat changes (208).

Research on the effects of dredging has been quite extensive. Information used in the Bio-Physical Checklist comes primarily from the technical appendices and Sorenson (167).

Filling and Spoil Disposal

Spoil disposal, as considered in the Bio-Physical Checklist, refers only to the deposition of dredge spoil in estuarine waters or in marshes and wetlands (excluding those sites that may lie inland). Spoil disposal is a consequence of the dredging activities previously discussed; wherever channels and marina facilities are being constructed or improved by dredging, disposal of the excavated material will be a problem.

Filling is often a means of creating additional area for the development or expansion of boat-related shore facilities, and marsh and wetland areas are often prime candidates for destruction by filling.

Utilization of marshes and wetlands for the disposal of dredge spoil, or the filling of them for marina construction, may result in severe depletion of the marsh vegetation, thus reducing primary productivity, and altering a habitat for numerous organisms.(167, 199, 119). As "filters" of pollutants and suspended sediments, they also affect water quality and turbidity levels (199). Spoil dumped in estuarine waters may smother shellfish and other organisms (199, 119, 240). However, McLeod (119) points out that recolonization generally takes place on the dredge spoil fairly rapidly.

Turbidity may be a problem at the disposal site, since much of the spoil remains in suspension. Contaminants that may be in the spoil can be released into the water, possibly being accumulated in the tissues of organisms (119).

An additional effect may be an increase in nutrients leached into the waters and a subsequent localized algae bloom (119).

Fills and spoil banks in the water restrict its movement, with possible consequent changes in habitat conditions: changes in nutrient and pollutant concentrations and retention times, changes in salinity, temperature, dissolved oxygen, mixing patterns, sedimentation, and shore erosion (239). Changes in species composition, usually reduction in numbers of individuals and in diversity and abundance of species, can be induced through the elimination of marsh and wetland vegetation, alteration of the substrate, and decreases in dissolved oxygen concentrations and increases in harmful substances in the water (167,119,240,208).

Most of the information presented is found in the Clark and Niering appendices, and additional information comes from Sorenson's work (167). There does exist adequate data on the impacts of filling and spoil disposal on esturaine ecosystems, for future applications to specific locational studies.

Channel alterations

Clark devotes several pages (239) to an evaluation of the impacts of channels and alterations made in existing waterways. The realignment, deepening, and widening of channels can cause reduced flushing and mixing of estuarine waters. When severe, this restriction of water circulation can lead to a major change in the dissolved oxygen concentrations of a water body, as well as a degradation of water quality in general, due to the retention of pollutants, increased temperatures, changed salinities, and reduced oxygenation of the water (239). Reduced circulation may also induce the precipitation of a blanket of sludge, which makes the substrate unsuitable for benthic organisms and rooted aquatics.

Freshwater inflows are often changed when channel alerations are made; if the salinity is greatly increased or greatly reduced, habitats can be altered, organisms can undergo changes in behavioral and reproductive patterns, and species composition can change (167). For example, anadromous fish migration may be restricted if salinity increases in the upstream areas where they spawn (239).

When channel maintenance necessitates periodic dredging, additional impacts may ensue. These have been discussed in prior sections.

Circulation problems can be especially severe in artificial, deep box-cut channels, when inadequate flushing causes stagnation of the water and a reduction in dissolved oxygen (239). As stressed previously, dissolved oxygen concentrations determine the kinds of organisms that inhabit a particular area, and changes in oxygen concentrations can substantially affect species composition.

Encroachment of structures

Clark (199,239) and Sorenson (167) consider the impacts of docks, piers, bridges, causeways, bulkheads, breakwaters, and other structures encroaching in water bodies and waterways. Immediately apparent is the fact that changes in water quality are induced when encroachment substantially restricts flushing and mixing of the waters in bay and harbor areas and in inlets and passes. These can in turn affect the habitats (water quality and substrate conditions) of benthic, littoral, and marine organisms, and induce changes in species abundance and diversity (167,239,119,208).

The influence of such structures on water quality and ecosystems is often overlooked once the initial construction period is over. However, it should be remembered that flushing rates are vital determinants of water quality and that restriction of water movement will have far-reaching consequences.

Further studies would be useful in providing data on the extent of changes in water flow patterns; design of structures should be such that their restriction of water flow is minimal. Information of this kind was not readily available in the literature identified under this study.

Navigational aids

Little data is available on the effects of navigational aids on wildlife. The types of aids considered in the bio-physical checklist are those that utilize lights or sounds in their warning signals. Responses of organisms to flashing lights or tolling bells are not well known, but it can be assumed that there is some influence on behavior patterns. Sorenson (167) indicates that navigational aids may cause abandonment of feeding and nesting grounds and inhibit reproduction, all of which, in severe instances, would endanger the survival of rare species. The present level of knowledge does suggest, however, that this impact is minor and that the beneficial effects of navigational aids outweigh any ecological disadvantages.

PHYSICAL-CHEMICAL IMPACTS

Disposal of Sewage and Trash

The introduction of large amounts of sewage effluent and foreign substances into a water body may degrade local water quality, be detrimental to the organisms therein, and create human health hazards. Several major problems can be created by the disposal of sanitary wastes in Bay waters. From a recreationist's standpoint, increases in the coliform content beyond a certain level mean that these waters must be closed to all water-contact recreation. Shellfish harvesting must also be prohibited, since shellfish are known to accumulate high concentrations of bacteria. In addition, refuse tossed overboard adds organic matter and in some cases, nutrients, and/or unsightly debris (litter) which may slosh around in the Bays and in harbors, sink to the bottom, or wash up on shore.

With regard to the presence of coliforms, Lear, et. al. (15) determined that a slight increase in coliforms occurred with the congregation of pleasure yachts, in a study undertaken at Miles River along the eastern shore of Chesapeake Bay. Hopkins and Sanderson (11) noted a significant deterioration in the sanitary quality of the waters of Selby Bay off the South River over the July 4th weekend, 1965, and predicted that health standards could be exceeded if the trends in increase in boating activities continued. Cassin, Smith & Frenke, (3), in a 1971 study of the Great South Bay off the south shore of Long Island, concluded that during the peak Labor Day period, coliforms entrained by clams were in excess of standards imposed by the New York State Department of Environmental Conservation. Also, Seabloom (22) concluded that the introduction of small boat wastes into two bays in the State of Washington clearly influenced the bacteriological quality of the water. However, while the above studies, together with other research noted in the bibliography, indicate definite relationships between wastes resulting from boating activity and water quality, it is difficult to assess the contribution of boating wastes relative to other contributors (e.g. septic tanks), particularly during peak periods when other recreation activities substantially increase. In addition, Furfari and Verber (7) point out that traditional coliform counts are not good indicators of waste disposal from small boats, as the input is in the form of fresh wastes rather than sewage.

An increase in organic matter, such as occurs when garbage is disposed of overboard, can stimulate an increase in the breakdown of such material. The bacteria that do this must consume oxygen in the process, and if the amount of organic matter being broken down requires more oxygen than is being replenished by aeration or photosynthesis, there will be a net decrease in the amount of dissolved oxygen available (224, 227). A major change in the dissolved oxygen concentrations in a water body can alter the habitat conditions, resulting in a change in species composition. Those species tolerant of low oxygen conditions will proliferate, whereas those species requiring high oxygen concentrations, usually considered as the more desirable species from a fisheries and game biologist's perspective, will diminish or disappear (161, 225, 226, 227).

If initial dissolved oxygen concentrations are high, the intensity of impacts resulting from sewage, trash, and debris disposal will not be high; but where dissolved oxygen is low, the introduction of excess pollutants and debris may produce significant deleterious effects.

Fourth, an increase in nutrients can result from sewage and trash disposal. A rapid increase in planktonic algae will most likely occur. The consequences of this so-called algae bloom are unpleasant conditions for swimmers and other recreational users of the water, and eventually, a hastening of the eutrophication process (119, 240).

Anti-Fouling Toxins

The paints which are used to coat dock pilings and the undersides of boats contain toxic substances to prevent the growth and encrustation of barnacles add other organisms. A commonly used anti-fouling agent is copper, which leaches into the water and which could reach damaging levels (119). It has been observed, by McLeod (119) and by Nixon, Oviatt, and Northby (136) that copper accumulates in the tissues of the fouling species but that it does not seem to be concentrated by other organisms inhabiting estuarine waters.

Stewart et. al. (90) have further studied the effects of copper from anti-fouling paints; the significance of these effects was noted to be largely dependent on flushing rates. Erickson et. al. (57) report an inhibition of growth of phytoplankton in waters of high copper concentrations. Heavy metals are studied by Lloyd (75) in relation to fish.

Gas and oil spillage

This is the field in which most boating-related research has been concentrated. Much of the stimulus for such investigation comes from the incidence of oil spills from commercial tankers and the widespread and severe consequences of such spills to all forms of aquatic life. Several of the references included in the bibliography are directed to this problem, but all are applicable to an analysis of the effects of gas and oil spillage associated with recreational boating.

Bell (38) and Clark (46) address themselves to the overall impact of oil pollution on aquatic life. Studies of a more specific nature are done by Carthy and Arthur (45) and by Cowell (47) in their works on oil pollution in relation to littoral communities. Brown and Tischer (41) and Blumer (39) are concerned with the decomposition and retention of petroleum products and hydrocarbons in waters and sediments. The effects of oil pollution on vegetation are considered by Baker (37), while numerous reports deal with the reactions of animal life to the introduction of hydrocarbons to their habitats: Anderson et al. (35), Farrington and Quinn (58), Hartung and Klinger (62), James (65), Lee, Sauerheber, and Benson (74), Pickering et al.(82), and Spooner (82). Moore, Dwyer, and Katz (88) include tables showing toxic effects of oil on finfish, shellfish, gastropods, and crustaceans.

Fuel from outboard motors, discharged into the water forms fine oil-water droplets that can be bound to the surfaces of organic sediments, sand, silt, and debris. In this manner hydrocarbons can be incorporated into the bottom sediments (31), changing the substrate to an extent, and being taken up by plants through their roots (30). When the plants die and decay, providing detrital matter for the consumption of other organisms, hydrocarbons may become concentrated in the food chain (240). Many hydrocarbons have been found to be carcinogenic (31, 32) and the severity of their impact may be magnified at each trophic level. More on carcinogenic hydrocarbons is found in Zobell (98). Sanders et al. point out, in addition, that oil, coating algae, marsh grasses, marine invertebrates, and crustaceans, will cause losses of these organisms (33).

Lobsters in general appear to be resistant to petroleum, and finfish, being mobile, can avoid areas where gas and oil spills occur. However, algae and the vascular plants of marshes are not, and when coated with oil, their photosynthetic processes are greatly reduced, which reduces the primary productivity in that area and possibly the productivity of the estuarine system as a whole. Bottom dwellers, such as bivalves, and littoral species, such as the gastropodds, barnacles, and tide pool organisms, are severely affected (119). Oil spills destroy the habitats of isopods, amphipids, and crabs. Diving birds are particularly susceptible to oil on the water's surface (167). Food-gathering activities of many organisms may be hindered (119). Oil and gas in the water can cause the flocculation and precipitation of suspended materials, and in this form become adsorbed by silt and clay particles in the bottom sediments, as described by Harrison (31). Besides being concentrated in plants and detrital matter, hydrocarbons can be accumulated directly by certain organisms, in particular the filter feeders--clams, oysters, and mussels. McLeod stresses that the severity of most of the above-mentioned effects depends on length of exposure (119).

The presence of a flotable scum on the water's surface has two major effects, described by Sorenson (167). First, the layer of oil and gas can prevent airborne oxygenation of the water, as a result of which the dissolved oxygen concentration gradually decreases as oxygen is used up by organisms. Secondly, the reduced light penetration can effect a decrease in the photo-synthesis of green plants, causing decreased primary productivity and in some cases decreased estuarine productivity.

Hydrocarbon pollution from recreational boating activities, though not as potentially damaging on a large scale as that from commercial tanker spills, may in some areas produce significant adverse environmental effects. In particular, where oil spills occur fairly regularly and at frequent intervals in the vicinity of marinas and service docks, aquatic vegetation in the area may be severely damaged through the introduction of toxins or smothering substances. However, MdLeod notes that there is very little information on the long-term sublethal effects associated with chronic, low-volume spillage (119).

Exhaust Fumes

The effects of exhaust emissions into Bay waters may be manifested in the tainting of fin- and shellfish flesh, including commercially harvested species (55, 93, 86), and in the degradation of air and water quality by the odor of fuel and exhaust emissions (99, 89).

Numerous studies have been undertaken on exhaust emissions in general, and with specific reference to tainting of fish and odor problems. English, Surber, and McDermott (55) determined in laboratory tests that outboard motor exhausts can produce an unpleasant taste and odor in water, resulting in the off-flavoring of fish flesh, if introduced into the water in significant amounts. Stewart and Howard (89) also report on exhaust induced odors in water samples.

Elaborate studies have been conducted by Kuzminski and others (68-72) regarding various effects caused by the introduction of exhaust emissions into water. Generally, they concluded that unless extremely high levels of fuel were burned and emitted into receiving waters by outboard motors, toxic effects on benthic and algal species were insignificant.

Engine exhaust and large scale marina parking facilities may both produce adverse impacts on air quality (99, 89, 167). The exhaust fumes produced by outboard motors have been considered nuisance factors by some critics. Further effects of airborne hydrocarbons on plants, wildlife, and humans are not fully known.

RELATIVE IMPACTS OF CAUSATIVE FACTORS

Neither the Bio-Physical Checklist nor the accompanying key attempt to show the varying degrees of impact of the causative factors considered. As discussed in the preceding sections, impacts vary with existing conditions in a specific area and with type of boating activity and on-shore facilities. Table 7, Relative Impacts of Causative Factors, has been developed to summarize how the impacts resulting from boating operational and facility factors compare relative to one another.

The matrix on page 90 lists bio-physical parameters across the top. This list is a condensed summation of the environmental effects, changes, and responses discussed in the previous sections. Causative factors associated with boating operational and facility factors are listed in the left-hand column of the matrix. These causative factors are linked to the bio-physical parameters in the matrix in order to depict the relative intensity of the potential impact of each factor on the environments of the Bay.

Potential impacts due to the operation of recreational boats were evaluated as a function of the activity they are associated with. To simplify this analysis, boating activities were divided into three classes: fishing, cruising, and waterskiing. The impacts of causative factors associated with sailing activities are negligible. Therefore sailing was excluded from the analysis. The potential impact of each causative factor on the bio-physical parameters can be traced through each of the three classes to provide an indication of the relative degree to which each boating activity affects the bio-physical parameters. The division into the three classes is intended only to be representative here. A more specific classification of boating activities was discussed in Chapter III of this report.

For analytical purposes, it was assumed that fishing takes place at low speeds, in activity periods averaging 7.48 hours, and within 5 miles of shore, 88.4% of the time. (166) There are generally less than 4 people/boat. (166) Cruising, on the other hand, was assumed to take place at higher speed ranges, and often in motorboats greater than 16' in length. 88% of cruising occurs within 5 miles of the shore, and the average outing time is 7.77 hours. (166) Third, it was assumed boats used for waterskiing must attain a minimum speed of 20-25 miles per hour. Waterskiing activity occurs with 1 mile of shore 80% of the time, and outings last an average of 3.06 hours. (166)

Impacts of on-shore facilities were broken down into those associated with marinas and those associated with docks and ramps. The impact of a marina was assumed to be greater in intensity than that of dock or ramp facilities because boats and related services are more concentrated in marina areas. On the other hand, a launching ramp often is no more than just that, with some parking provided, and in some cases, picnic facilities. Service or mooring docks cannot accomodate the numbers of boats which most marinas can, so a less severe impact can ge predicted. In the Chesapeake Bay area there are many more marinas, public and private, than there are dock and ramp facilities. (210)

Table 7

Relative Impacts of Causative Factors

BIO-PHYSICAL PARAMETERS / CAUSATIVE FACTORS	Water Circulation: flushing, mixing, fresh-water			Sediment Resuspension						Erosion						Sedimentation			Substrate			Turbidity			Salinity			Temperature		
				fine			coarse			high rate			low rate																	
OPERATIONS	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski
PHYSICAL																														
Propeller Cutting																			L	L	L									
Boat Wake				M	H	H	L	L	M	M	H	H	L	M	M	L	L	L	L	L	M	M	H	H						
Propeller Wash				M	H	H	L	L	M										L	L	M	M	H	H						
Noise																														
PHYSICAL-CHEMICAL																														
Sewage Disposal																														
Trash/Debris																			M	M	L	M	M	L						
Anti-Fouling Toxins																														
Gas & Oil Spillage																			L	L	L									
Exhaust Fumes																			L	L	L									

BIO-PHYSICAL PARAMETERS / CAUSATIVE FACTORS	Dissolved Oxygen						Water Quality						Aquatic Vegetation			Marshes & Wetlands			Wildlife			Littoral, Benthic, & Marine Fauna			Air Quality		
	high concent.			low concent.			high flushing			low flushing			incl. phytoplankton														
OPERATIONS	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski	Fish	Cruise	Ski
PHYSICAL																											
Propeller Cutting	L	L	L	M	M	M	L	L	L	M	M	M	M	M	M				M	M	M	H	H	H			
Boat Wake							L	M	M	M	H	H	L	M	M				L	M	M	L	M	M			
Propeller Wash							L	L	L	L	M	M	L	M	M				L	M	M	L	M	M			
Noise													?	?	?				L	M	M	?	?	?			
PHYSICAL-CHEMICAL																											
Sewage Disposal	L	M	L	M	H	M	L	M	L	M	H	M							L	L	L	L	M	L			
Trash/Debris	M	M	L	H	H	L	M	M	M	H	H	H							L	L	L	M	M	L			
Anti-Fouling Toxins							M	M	M	H	H	H	L	L	L	L	L	L	?	?	?	L	L	L			
Gas & Oil Spillage	M	M	M	H	H	H	M	M	M	H	H	H	H	H	H	M	M	M	H	H	H	H	H	H			
Exhaust Fumes							M	M	M	H	H	H	H	H	H	M	M	M	M	M	M	H	H	H	H	H	H

BIO-PHYSICAL PARAMETERS / CAUSATIVE FACTORS	Water Circulation: flushing, mixing, fresh-water		Sediment Resuspension				Erosion				Sedimentation		Substrate		Turbidity		Salinity		Temperature	
			fine		coarse		high rate		low rate											
FACILITIES	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps
PHYSICAL																				
Dredging	H		H		M		L		L				H		H		H		H	
Filling/Spoil Disposal	H		H		M		L		L		H		H		H		H		H	
Channel Alterations	H						M		L		H		H		L		H		H	
Structure Encroachment	H	M					M	L	L	L	H	M	H	M	L	L	H	M	H	M
Navigational Aids																				
PHYSICAL-CHEMICAL																				
Anti-Fouling Toxins																				
Gas & Oil Spillage													L	L						
Sewage Disposal																				
Trash/Debris													M	L	M	L				

BIO-PHYSICAL PARAMETERS / CAUSATIVE FACTORS	Dissolved Oxygen				Water Quality				Aquatic Vegetation		Marshes & Wetlands		Wildlife		Littoral, Benthic, & Marine Fauna		Air Quality	
	high concent.		low concent.		high flushing		low flushing		incl. phytoplankton									
FACILITIES	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps	Marinas	Docks & Ramps
PHYSICAL																		
Dredging					M		H		H		H		M		H			
Filling/Spoil Disposal	H		H		M		H		H		H		M		H			
Channel Alterations	H		H		M		H		L						H			
Structure Encroachment	M	L	H	M	M	L	H	M	L	L	M	L			H	M		
Navigational Aids													L	L				
PHYSICAL-CHEMICAL																		
Anti-Fouling Toxins					M	L	H	M	L	L	L	L	?	?	H	M		
Gas & Oil Spillage	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H		
Sewage Disposal	M	L	H	M	M	L	H	M					L	L	M	L		
Trash/Debris	M	L	M	M	M	L	H	M					L	L	M	L		

SUMMARY: ECOSYSTEM CARRYING CAPACITY CONSTRAINTS

The recreational boating carrying capacity criteria discussed in Chapter III, relate only to the idealized surface area needs of various boating activity types. As such, they are useful as first-round planning tools in the field of boating impact management. However, as the focus of inquiry begins to narrow towards the determination of site-specific carrying capacity standards, the planner and the decision maker must modify those standards in light of identified environmental susceptibilities to boating activity and construction. Specifically, given environmental parameters become constraints upon boating related activities for either of two reasons; they directly affect the exercise of a given activity within the geographical area under consideration, or they render that area especially susceptible to adverse environmental impacts from boating activities and related facilities.

The effects of the former were discussed in Chapter III. These primarily include physiographic constraints: depth of the water body, openness of the water body, configuration of the shoreline, and the distance from shore where boating activities can take place free from physiographic constraints. These constraints will influence the location of boating activities and will affect the levels of congestion over the water surface.

From an analysis of the material presented in this chapter, key environmental constraints to boating activities in the Chesapeake and Chincoteague Bays have been identified as warranting consideration in the planning and regulation of future boating activities within the bay region. These constraints include: depth of the water body, water body type, shoreline erodibility characteristics, tidal flushing rates and circulation patterns, location of wetlands and productive marshes, location of rooted aquatics, location of finfish spawning areas, and location of shellfish beds.

Delineation of these constraints in map form has been undertaken in Part I of this study (see appendix C) and will be used in Part II to identify those areas of the bays especially susceptible to adverse impacts from boating activities and related facilities. A discussion of the rationale for selecting these constraints as indicators of areas subject to potential adverse impacts follows. A discussion of how the mapping of these constraints will be applied in the Boating Capacity Planning System is included in Chapter VI.

1) Depth

Depth is an important parameter with regard to the ecological sensitivity of a given area. Shallow areas are more vulnerable to turbidity and sedimentation induced by boating activities than are deeper areas. In Chesapeake and Chincoteague Bays this is of particular importance because many of the shallower areas are used as primary spawning areas by sensitive fin and shellfish species. In addition, water depth affects tidal flushing, which is an important determinant of sustained water quality, and thus the ability of a water body to absorb boating impacts.

2) Water Body Type and Width

Classification of water body types is important in determining an area's ecological sensitivity due to the effects that shoreline configuration, water body size, and water depth have on the local flushing rates and circulation patterns. For example, a broad river reach, or a wide coastal embayment will be tidally flushed in less time than a logoon or embayment made up of many complex branched inlets. With other conditions being equal, the former will be less sensitive to boating related impacts than the latter, since potential pollutants will be more rapidly flushed from the area.

3) Shoreline Type and Erodibility

As described in earlier sections of this chapter, soft shorelines are especially vulnerable to boating relative impacts. Specifically, the most pronounced impact may be accelerated erosion of the shore resulting from the constant pounding of boat-generated wake. This problem is severe in several areas of the bay region as evidenced by the numerous requests submitted by property owners to the Maryland Department of Natural Resources, asking for the imposition of boat speed limits to reduce erosion damage to their waterfront properties. In addition to the losses of public and private property, accelerated erosion may further destabilize the shoreline ecosystems and aggravate problems resulting from turbidity and sedimentation. In those Bay subareas where natural processes lead to high rates of shoreline erosion (greater than 0.2 acres/mile/year) careful attention must be paid to ensure that boating operations do not exacerbate a currently severe problem.

4) Tidal Flushing

The ability of an estuarine water body to adequately cleanse itself of pollutants will be determined to a large degree by tidal flushing rates and circulation patterns. In a well flushed area, impacts resulting from the introduction of low amounts of pollutants, although of potential local significance may be of relatively short duration. Such areas can be considered to have the ability to support high levels of boating activity, unless the kinds of proximities of sensitive biota are such that even low levels of unaviodable boating pollution threaten serious harm. A poorly flushed area will be especially sensitive to such impacts, and may therefore be unable to support the number of boats suggested by an operationally derived carrying capacity standard.

Many larger tributaries of Chesapeake Bay are apparently well flushed by combinations of river inflow and tidal action. However, it is in the smaller tributary, creek, or enclosed estuary, that most boating facilities and activity origins are located at present. For planning purposes, therefore, local flushing rate and circulation pattern data, integrated with a comprehensive analysis of ambient water quality parameters, should be considered in evaluating the capacity of a water body to support given levels of boating activity. The availability of such information will determine the extent to which these factors can be adequately considered.

5) Wetlands and Productive Marshes

Wetlands and marshes are among the most important components of any estuarine ecosystem. Marshes provide food and shelter to many species of birds, mammals, fish and shellfish, and other forms of terrestrial and aquatic life. Wetlands and marshes are important sources of nutrient to surrounding water systems. They also function as natural protection against storms and erosion. However, they are particularly sensitive to impacts generated by excessive boat traffic, particularly by oil and fuel spillage. Marsh edges which are soft earth banks or where the highly wave-resistant spartina alterniflora has been stripped away and S. Patens lies exposed, may be particularly vulnerable to aggravated erosion resulting from excessive wake. Such edges should be identified for boating capacity-planning purposes.

6) Submerged Grasses

As with wetlands and marshes, submerged grasses are critical components of sound, productive ecosystems (239). They provide feeding and nursery areas for a variety of aquatic species, oxygenate the water, provide nutrients, and stabilize bottom sediments. Given their potential sensitivity to propeller cutting, turbidity and sedimentation, and the hazard which they pose in terms of propeller fouling, the presence of submerged grassbeds in shallow depths should be carefully considered in boating capacity planning.

7) Finfish Spawning Areas

The Chesapeake Bay region has long been one of the most important and highly valued recreational fishing areas in the nation. The water of the Bay and its tributary river systems abound with a large number of finfish species, including herring, shad, alewife, menbacken, white and yellow perch, bluefish, flounder, striped bass, and more. A number of important species, including herrings and bass, spawn in shallow, low salinity upstream reaches during late winter and early spring. Their eggs and young may be particularly vulnerable to boating-originated toxic impacts. Thus, power boating activity in spawning areas should be restricted prior to and during the spawning season.

8) Shellfish

Clam and oyster beds represent one of the most important commercial aquatic resources present in the Chesapeake and Chincoteague systems. Being filter feeders, shellfish are also particularly sensitive to boating related impacts. Thus, the locations of these areas should constitute constraints on boating activity.

CHAPTER VI

BOATING CAPACITY PLANNING SYSTEM

INTRODUCTION

Earlier, a number of general critieria were cited for ensuring that a carrying capacity management system would be capable of optimizing boating recreational satisfactions while preventing environmental damage.

Additional criteria, relating to the workability of the method, were employed by the consultants in the selection of the recommended system in order to ensure that its use by Maryland's Department of Natural Resources and other involved agencies would be as effective as possible in achieving the state's objectives. In brief, these critieria required that a boating capacity planning system would:

1) Provide for interrelating environmental sensitivity data with boating activity and facility planning. Without a means for sounding the alarm when impact occurs and for acting upon receipt of the signal, monitoring the environment will remain an academic exercise.

2) Evaluate the boating resource supply realistically. Consider not just the theoretical carrying capacity of each water body, but related land use, community preferences, and landscape and ecosystem qualities as well.

3) Attend to questions of use peaks as well as average demand. Average demand will help determine the extent of needed new facilities, but it is peaking (densities and intensities) which generally contributes to impact on user satisfaction or environmental quality, or both.

4) Be comprehensive, yet simple. The system must consider all aspects of boating and identified environmental sensitivites, yet it must be simple

enough to be easily understood and handled by field personnel, managers, and the general public.

5) Be dynamic. After the baseline studies (including this report) are completed, and projections of needs and plans made, the system should be able to rapidly accommodate data derived from new surveys and on-going monitoring.

6) Provide quantitative data on all factors where possible, but should also provide means for professional judgment on factors not practicably amenable to quantification. There will be no practicable way other than professional judgment to determine the scenic value of a given shore area or to evaluate the legitimacy of property owners' opposition to the expansion of an abutting marina. Particularly in light of the present poor state of knowledge in the areas of boating user satisfactions and in boating environmental impact, the Maryland official with boating planning or management responsibilities should be supported with a system that can rely on sound judgment.

7) Consider non-boating aquatic recreational supply, demand, and needs. Swimming, shore recreation, and shore fishing are important factors that interface with boating.

8) Distinguish between water surfaces used for points of departure (e.g. anchorages and launching ramps), passage (e.g. streams and channels), and destinations (e.g. activity areas).

9) Base use and peaking estimations on measurement field counts by Marine Police boat and plane, as well as by (future) remote sensing systems.

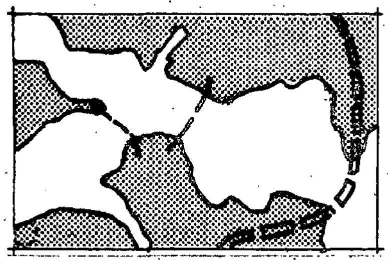
THE RECOMMENDED SYSTEM

The 11-step planning system described on the following pages is designed to meet the previously defined criteria. Whether it can be judged as meeting the needs of the Department for a planning framework within which both boating recreational satisfactions and environmental protection can be accomodated will be seen only with the testing of the system planned in Phase II of this study (reported in Part Two of the report) and with the test of time if the system is adopted for Departmental use.

As noted, the system design criteria favored the selection of a simplified approach to enhance its practical use. Nevertheless, future efforts should be undertaken to establish automated, computerized processing and evaluation of data received from the field relative to conditions within management units. Computerized mapping should be considered as future Departmental capabilities permit, to enhance the reliability of representations made of observed or measured changes in sub-bay capacities, boating activity, or environmental quality. Remote sensing systems, utilized on a periodic basis, could fill important roles in the detecting and recording of boating activity and congestion, as well as in possibly correlating activity patterns with certain environmental effects.

For the immediate future, however, the recommended system should meet the Department's objectives with ample effectiveness.

1. Unit Area Delineation

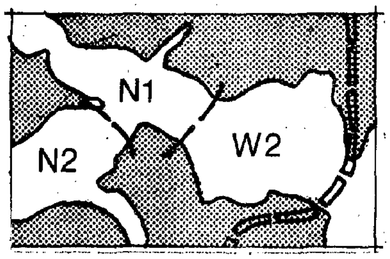


The delineation of management units within sub-areas of Chesapeake and Chincoteague Bays is an essential first step in developing a viable boating capacity planning system. Delineations of sub-areas of the Bays, which are termed sub-Bay units, and their subsidiary components, the management units, have been made by the consultants and are presented on the county maps.

The primary basis of delineation of the sub-Bay units is the location of sub-sub-watershed divides, which in turn are the delineators of water basin quality management areas under the standard classification system adopted by the U.S. Environmental Protection Agency and the Maryland Water Resources Administration. This sharing of a common basis of delineation will be beneficial, since water quality monitoring and evaluation can lead directly into suitable geographical management frameworks where boating environmental impact is concerned.

The primary basis of delineation of the management units is landform, and allows the identification of water surfaces set off from others by capes, points, spits, bars, and other promontories with navigational or operational significance. The same landforms are also indicative of constrictions in the water system which may act as factors in circulation and tidal flushing. The latter are important influences on ecosystem response to man-made impacts.

2. Water Body Classification



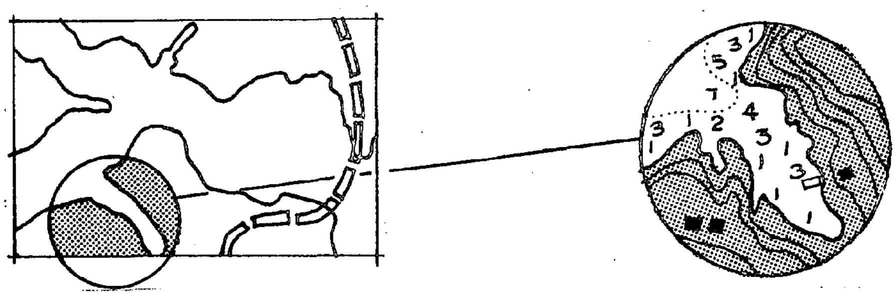
The second step in constructing a boating capacity planning system is the classification of the water bodies--sub-Bay units and management units--delineated earlier. The purpose of classification is to establish characterization in terms of two morphological parameters important to both boating operations and environmental quality: water body size and shape and generalized shoreline configuration. The former will provide a clue as to the general capacity of the unit in question to sustain types of activities, numbers of users, and use intensities. The latter will indicate the general extent of the inshore zone which is partially or wholly protected from through speeding by shoreline indentedness. The indices which are employed in this report's county maps are:

Water Body Type (Size and Shape)	Example
A Open bays	Upper Chesapeake Bay (Cecil/Harford)
B Small bays/river mouths/open river reaches	Chester River (Kent/Queen Annes)
C. Moderate width river reaches/ semi-open creeks	Patuxent River (Calvert/St. Mary's)
D Upper river and narrow reaches/ semi-enclosed creeks/confined and compound estuaries	Upper Severn River (Anne Arundel)

Shoreline Configuration	Example
S Simple (smooth/flat)	Holland Point (Anne Arundel/Calvert)
M Moderately indented	Elk River (Cecil)
C Highly indented	Choptank River (Dorchester)

A third classification parameter, bottom depth, is no less important than the two described here, and will be investigated and reported in Part Two of this report. Bottom depths and contours are significant determinants of circulation and flushing, which, together with shoreline configuration, exert a strong degree of control over the disposition of pollutants that enter any given water body. The level of investigation of depth in Part Two will also necessarily be generalized. It will remain the task of an ongoing research and monitoring effort, under the planning system, to confirm the location of bottoms supporting sensitive or valuable environmental features and the shore or water areas where, with tidal influence, boating activity or facility development can affect these features.

3. Detailed Shoreline and Nearshore Analysis



Utilizing 1:24,000 scale topographical maps, nautical charts, the Maryland statutory wetlands maps, and available maps or plans of larger scale, the

planning system will analyze shorelines and benthic areas in order to determine:

a) the accurate location of existing eroding shorelines

b) the location of steep shores in excess of percentages safely below threshholds of erosion-proneness

c) the accurate location of wetlands

d) existing land uses sensitive to boating facility development or expansion

e) transportation access

f) location of soft bottoms within the 6' contour

g) location of the 4' contour in areas of sandy bottoms which are not within impact proximity of sensitive environmental resources

This information will allow the planner to delineate shore areas where boating facility or related development should not take place for reasons of wetland displacement, erosion and resulting sedimentation, and land use, or zones in which prop wash and other factors may cause significant turbulence, mixing, and impact on sensitive biota (e.g., see Table 6). The use of the 6' contour at this time is recommended as a minimum precautionary depth for planning purposes, although current research (e.g., EPA, 1974, No. 107) has revealed evidence of mixing resulting from outboard motor operation to depths of 15 feet.

4. Benthic Life Analysis

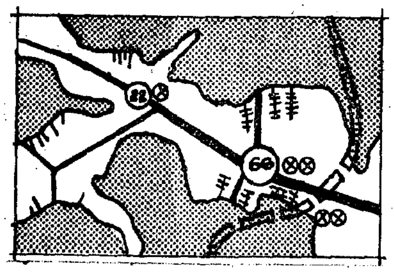
In addition to the identification of environmental sensitivities in the shallow zones, accurate location of benthic life sensitive to boating impact factors in the deeper waters should be made. Locations of oyster and clam (hard and soft) beds would be derived from the planned revised mapping of these resources by the Department of Natural Resources. Specific locations of fish spawning areas of indicator species and their seasonal limits should be recorded.

Table 8

Generalized Shoreline Suitabilities for Boating Facilities

Boating Facility Type / Shoreline Type	Bluff	Rising or Flat Shoreland		Marsh
		High-rate eroding shoreline	Low rate eroding shoreline	
Marinas, Other large facilities	Low suitability Excavations in bluff will tend to cause or increase erosion and aesthetic adverse impact is probable.	Low suitability (critical)	Moderate to high suitability. measures to control erosion, water run-off, and spillage of fuel, oil, and paints on drained surfaces should be adopted	Low suitability (critical)
Single piers	Moderate suitability, depending on adequacy of access to pier without need to excavate bluff-face.	Low to moderate suitability. Pier should carry over shoreline on pilings and abut into grade at safe distances inland.	Moderate to high suitability. Pier should be on pilings	Low suitability, except where constructed on pilings with minimum marsh (moderate suitability)
Public landings (launching ramps)	Low suitability, except where restricted parking spaces may be accommodated at bluff base without need for excavation	Low suitability (critical)	Moderate to high suitability. Measures to control erosion, run-off, and spillage of fuel and oil should be adopted.	Low suitability (critical)

5. Existing Peaking and Congestion Determination



Since the capacity planning system is intended to deal with problems of limits, peak use during peak use periods is of primary importance for determining whether use is approaching capacity. Important factors are:

a) the numbers of boats moored at each boating facility, including owner association and individual finger piers (aggregated for each management unit)

b) observed percentages of boats under way for each facility at peak times during important weekends and seasons (important recreationally or ecologically)

c) the numbers of trailerboat spaces at public landings

d) observed percentages of boats occupied by users at dockside only

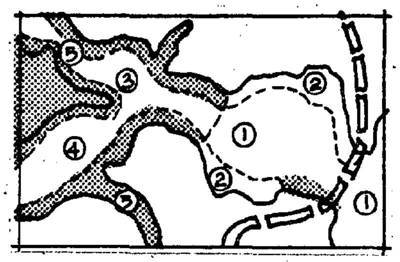
e) observed aggregated numbers of boats, by type and class, for water surfaces distinguished as to (f):

f) differences between areas of origin (moorings, landings), areas of passage, and destinations (activity areas)

g) observed accident occurrences

h) other conflicts

6. <u>Use Zone Delineation</u>



1 general activity zones

2 harbor zones

3 passage zones

4 special activity zones

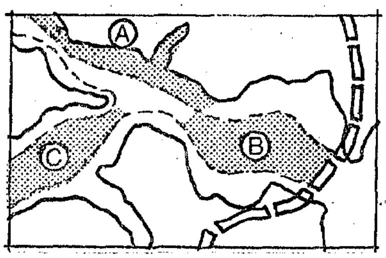
5 inshore zones

Prior to determining general capacities in terms of numbers of boats or users, individual zones within management areas should be established and should be based on the physical and navigational-operational criteria discussed above. This delineation should be made irrespective of policies and priorities for use, in order to establish zone boundaries that reflect basic morphological characteristics. In the following step (Step 7), each such zone will be evaluated in terms of boating recreational needs, and environmental, social/land use, aesthetic, and safety considerations.

Delineation of zones at this or successive stages need not be interpreted as the establishment of regulatory zones, although this latter effort, for specific areas of conflict congestions, is a recommended procedure under Step 7.

The proposed harbor zone designation would be applied to existing facilities and approach waters and sites evaluated as suitable for future facilities. Passage zones would include all channels, and where considerable traffic can be identified in lateral areas along channels, in the latter as well. In cases where narrow river or creek reaches serve as important and heavily traveled through ways between origin and destination points, the major portion of the stream's cross-section would be identified as a passage zone. General activity zones would include those water surfaces which are sufficiently large to accomodate most uses with negligible conflict. Special activity zones are water surfaces which are generally smaller in size and which offer opportunities for such activities as water skiing, rowing, or fishing, but cannot support mixed use without substantial conflict. Inshore zones are the shallow areas along shorelines in which lower boating intensities are indicated as being desirable from the point of view of bottom disturbance, safety hazards, vegetative features, or use conflicts. The inshore zone limits can be delineated along the 4' or 6' contours discussed under Step 3 or where additional data can identify a desirable line.

7. Use Priority Designation



examples:

A low speed cruising--less than 15 knots

B general activity

C waterskiing

The establishment of use priorities in the delineated use zones will need to be based on Departmental policies, recreation needs, environmental sensitivity indicators, community-property owner desires, and other considerations that have been identified through the boating capacity planning process.

The priorities established in this step may serve either as general policy guides for the Department and county and local officials and the public, or as the basis for actual regulatory zoning. Zoning presently exists in Maryland waters in limited form; power vessels towing water skiers, aquaplanes, or similar devices must keep at least 100 feet from any shore, wharf, pier, bridge structure or abutment, or people in the water (MDNR Boating Regulations, Section 08.04.22). It may be desirable to enlarge this 100 foot zone in certain areas of high sensitivity. High speed power operation in such zones may also be excluded. The same zones would become more available for other priority uses as a consequence. Dropline fishing or casting, sailing, and low speed cruising are among uses that could benefit from such zone redefinition.

At the same time, in consideration of the need to accommodate the growing interest in waterskiing, water surfaces judged particularly suitable for intensive waterskiing activity could be zoned for this purpose. Such zones could be marked and identified by buoys as well as on State maps and informational material distributed at marinas and rental facilities.

In areas of particular high sensitivity, including undeveloped or "primitive" reaches of remote enclosed estuarine waters, more restrictive zones would be established.

8. Development of Boating Activity Models for Management Units

In view of the difficulties of constructing fixed standards for boating carrying capacity, particularly for areas in which mixed activity is common, a desirable management objective would be the development, for each management unit, of a simple base model and a mechanism for its modification with data received from the field on observed problems.

The model should identify the peak usage hypothetically possible under both mixed use and single use conditions for open water zones (i.e. excluding inshore and shallow waters where speed and activity regulations should exist). Modification and weighting should then be made in consideration of the following factors:

a. function of the open water zone as an origin, passage, or destination (activity) area, or as a combination of these
b. observed congestion
c. accident occurrence

d. proximity to marinas and other points of origin

e. observed conflicts with other navigation, aquatic recreation sites

f. degree of protection from storms

Environmental constraints will be applied to the modified model under Step 9.

Specific calculations of boating capacities in Chesapeake and Chincoteague Bays had not been made by recreation investigators as of 1974. The general boating operation spatial and activity requirements presented in Chapter 3, however, may serve as initial guidelines for capacity planning, while testing of the recommended model for key managmement units of the Bays will be found in Part Two of this report.

It should be borne in mind that the model, as modified, is not to be considered a regulatory mechanism in itself, but a guideline for a) instituting regulatory measures such as water zoning, speed limits, and activity exclusions, and b) formulating decisions on permit applications for marina development or expansion, and on boating facility planning for State park and other public areas. (Both a) and b) are acted upon under Steps 9 and 11.)

It should be further noted that recreational boating user demand patterns are not among the modification/weighting factors to be considered in refining an assessment of capacity. Were demand to be used thus in this step, a self-fulfilling demand and development cycle might be established. The appropriate meshing of demand follows the full definition of constraints, i.e., <u>following</u> capacity guideline refinement and further modification relative to environmental sensitivities under Step 9.

The locations of existing marinas and public landings are identified on the county maps of Part One of this report. Accident loggings for selected years are indicated on page 13 .

In this Step, the surveillance and field monitoring capabilities of the Maryland Marine Police will be of prime importance, since it is this professional arm of the Department of Natural Resources that is in closest contact, on a day to day basis, with occurrences of congestion and accidents. In Part Two, this report will detail recommendations on procedures that will allow the Marine Police, as well as other Departmental officials, to document occurrences of boating activity peaking, congestion, conflict, and user dissatisfaction with greater efficacy. Recommendations will also be detailed as to improved utilization of the data recording and processing capabilities of the Boating Registration Division of the MDNR, to facilitate a better pinpointing of the profile of boating activity potentials in each management unit of the Bays. Although not practicable at this time, future possible utilization of remote sensing of boating activity patterns and shoreline use, on a periodic monitoring basis, should be carefully considered.

9. <u>Modify Activity Models with Data on Environmental Sensitivity and Institute Management Measures</u>

The development of a reliable environmental baseline for boating-sensitive biological and physical indicators in the Maryland Bays is far from complete. Yet, while further research is needed and in fact must be acknowledged as a component of any boating management framework for the Bays, the indicators of environmental sensitivity ("constraints") displayed in the county maps of Part

One may be reliably referenced in modifying the boating capacity guidelines developed under Step 8. Environmental research on boating impact, as reviewed in the text, appendix, and annotated bibliography of this report, supports their use as indicators. The principle of restraining boating acitivities to levels safely below those at which serious impact threshholds occur in environmentally sensitive areas of the Bays implicitly requires a good margin of safety where proven impact causative factors are operative.

Two significant sensitivity indicators related to benthic patterns, in addition to the factor of depth itself, will need to be carefully addressed in the eventual planning system by the Department, and will be reviewed at a general level in Part Two of this report. Flushing rates, which are a function of the speed at which the water within a portion of the estuary will be replaced through tidal action combined with freshwater inflow, are an important indicator of the degree to which the given estuarine portion can recover from water quality degradation. If the boats moored at a large marina, on a July 4th weekend, for example, release a loading of pollutants that might be judged borderline under average circumstances, a high flushing rate would possibly reduce most pollution effects considerably, while a low flushing rate might ensure a case of appreciable, although possibly transitory, aggravation of pollution effects on water quality.

At the time of writing of Part One, flushing rates were being computed by the Department of Natural Resources for the major tributaries of Chesapeake Bay and for Chincoteague Bay.

The second significant sensitivity factor is circulation. This factor, because of the intricacy of depth patterns throughout the Bays, can be effectively integrated into a boating capacity planning system only with substantially more research and investigation than have been carried out to date. The studies presently under way by the Department on flushing rates will yield information on overall flushing for the major Bay tributaries, but it will remain difficult to extrapolate this data to the smaller estuarine reaches, because of depth and circulation vagaries, without further investigation.

Both latter factors, however, are essential in considering the relationships between boating impact and environmental sensitivity indicators. Part Two will explore both in assessing the needed modification of the Boating Activity Models (Step 8) to meet the constraints of safe level environmental protection developed here.

In practice, modifications to the Step 8 Boating Activity Models would potentially include the establishing of speed and high wake restrictions in proximity to shorelines of high erodibility, the restricting of construction or expansion of marinas in shallow waters where the probability of resuspension, transport, and redeposition of soft bottom sediments or of toxic substances on nearby oyster beds is appreciable, and similar measures.

Yellow Flag/Red Flag Management Measures

The institution of environment-protective measures described immediatly above is designed to provide the safety margin below threshholds of environmental degradation described earlier as a key criteria to the recommended boating capacity planning system.

Areas in which one or more such measures are required may be termed Yellow Flag Areas, to express the need for precautionary actions. An area so designated should be surveilled and monitored with sufficient frequency to ensure that boating satisfactions are achieved without adverse environmental effects and to record adverse or beneficial changes in the quality of sensitivity indicators.

In the event that monitoring of the aquatic environment reveals that the initial conditions have improved, the area can be relieved of the specially instituted measures.

In the event that the initial conditions become aggravated to the point of incipient or actual adverse environmental effects, a Red Flag status may be defined. Under this status, more serious restrictions may be applied until conditions are improved.

The specification of management measures for the control of recreational boating in Yellow Flag and Red Flag areas will be made in Part Two.

The underlying purpose of the Yellow Flag - Red Flag approach is to ensure that a buffering safeguard exists between natural or assigned limits of boating activity and actual capacity, i.e. the threshholds of environmental degradation.

10. Determine Existence of Excess or Deficit Capacities for Each Management Unit

This Step is straightforward: the difference between the modified activity model capacity (modified for both boating operational and environmental needs) and the observed user numbers or numbers of boats active at peaking periods will provide an indication of whether an excess or a deficit in boating capacity exists for a given management unit within the Bays.

Provisional determinations of probable excess or deficit will be presented in Part Two. Confirmation or revision must be performed, however, as part of the continuous monitoring and management program recommended for the Department of Natural Resources. The provisional determinations of Part Two must be checked in the field and from updated information from boating registry and other inventory sources on a periodic basis to establish whether new users or use intensities have consumed excess capacities or have reversed deficit situations. Environmental monitoring will also play a continuing role in updating evaluations of the constraints needed to provide safe margins between use and impact threshholds.

11. Develop Recommended Program for New and Expanded Boating Facilities

Under this Step, planning for new and expanded public facilities as well as guidelines for private facility permit processing, can be undertaken with full consideration of the capacity status of the defined management units of the Bays. Synthesis must be made, of course, of the findings of the antecedent Steps of the boating capacity planning system, with knowledge of important related areas: highway and feeder road access, land use zoning, community preferences, state and county park and recreation capital programs, state-wide and regional boating demand projections, and other factors. The demand projections and the questionnaire presented in Part Two will help define where unsatisfied demands exist. The boating capacity planning system will help determine where suitable locations exist that can meet these demands.

CHAPTER VII

RECOMMENDATIONS

RECOMMENDATIONS

1. Improve Procedures for Data Collection

The boating accident report forms employed by the Maryland Marine Police should be modified to make possible the recording of the specific location of boating collisions, water skiing accidents, and other congestion related accidents. The specific courses of involved boats should be marked on 8½" x 11" simplified maps of the sub-bay area in which the accidents or collision occurred.

Boating registration and renewal and titling application forms should be adapted and supplemented with 8½" x 11" simplified county maps to provide for reliable recording of the specific locations of moorings, preferred launching sites and preferred activity areas. Named identifications of these locations, as well as verbal identifications of preferred activities, times of day, calendar dates, and frequencies should be recorded as well.

The data so recorded should be processed and evaluated on a regular (annual) basis or upon need, to improve the Department's knowledge of boating demand, to help determine whether use may be approaching the calculated capacity of given management areas, and to aid in boating facility planning.

2. Adopt a Boating Capacity Planning System

The 11-step planning system described in this report is recommended for adoption by the Department. The proposals contained in the planning system description (Chapter VI) are to be considered integral with this Recommendations summary.

3. Develop Field Monitoring Systems

The Department should develop field monitoring systems capable of surveilling water quality effects of recreational boating in loci of high intensity. Airborne, remote-sensing, and water surface monitoring systems should also be developed for detecting occurrences of repeated boating congestion and activity conflict.

4. Improve Regulation and Control of Adverse Activity

Data from both monitoring systems should be evaluated and acted upon to abate detected boating-caused pollution or congestion. The utilization of speed limits, water use-zoning, engine maintenance and muffling requirements, and other measures should be used with greater scope and selectivity to enhance remedial controls.

5. Provide Expanded Opportunities for Boating In Suitable Capacity Areas

Construct new large-scale boating facilities in appropriate locations, on environmentally suitable shorelines and easily accessible to water bodies with excess or unused boating capacities. Locations upstream of low level bridges or inconsistent with regional road access capacities should not be selected. The demand projections and facility site planning and design criteria presented in Part Two of this report should be considered for guidance in facility development.

New large-scale facilities should be developed by the Department of Natural Resources to meet a portion of the apparent high unmet demand for access, berthing, and storage. The additional laucnching and berthing capacities needed in the Bays, and selected recommended facility sites are considered in Part Two of this report. Private facility development should also be encouraged. In both instances, the approval of environmentally unsuitable sites should be avoided.

6. Extend Research

New and expanded research into recreational boating environmental effects, exhaust and waste disposal systems, engine modifications, boating user expectations and preferences, and monitoring and detection systems should be programmmed by Maryland or by others with the State's support.

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1) Boating related impacts - Biological
2) Boating related impacts - Chemical
3) Boating related impacts - Physical
4) Boating related impacts - General
5) Marina management and operations; related impacts
6) Recreational planning; access considerations
7) Carrying capacities; zoning and other regulatory mechanisms
8) Estuarine processes; disruption and modelling
9) Chesapeake Bay regional background information and existing conditions
10) Recreational boating information and statistics

Given the great number of references comprising the product of the literature review, it was decided that only abstracts of selected references should be included within this report. Selection of these references was done through consultation with the authors who have submitted background papers as appendices to this report. The abstracts include author abstracts as well as those prepared by the Roy Mann Associates Staff.

Items for which abstracts are provided are identified in the bibliography by the symbol (*), preceeding the author listing. Abstracts are grouped sequentially at the end of the bibliography, and reflect the organizational structure used in the literature review.

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XI Background Papers Appearing in the Appendix of Recreation Boating Impact Study, Part 1: Boating Capacity Planning System

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240. Niering, William A. " Biological Effects of Motorized Boating on the Tidal Marsh Estuarine Ecosystem ", paper submitted to Roy Mann Associates, Cambridge, Mass. Sept. 1974.

ABSTRACTS

I Boating Related Impacts - Biological

■ Clark, B.D., "Houseboat Waste Characteristics and Treatment," report #PR-6, Corvallis, Oregon; Federal Water Pollution Control Administration, Pacific Northwest Water Lab, September, 1967.

It was found that the average per capita BOD5, per capita suspended solids, grease, and oil in the houseboat waste is higher than normal domestic sewage and waste from the average land residence. Small extended aeration biological treatment units seem to offer a practical means of economically providing secondary treatment for houseboat wastes. The average daily flow, concentration, and treatment problems are discussed.

■ Clark, B.D.,"Houseboat Waste: Methods for Collection and Treatment," Corvallis, Oregon: Federal Water Pollution Control Administration, Pacific Northwest Water Laboratory, 1967.

The study area included the States of Washington, Oregon, and California which have over 1200 houseboats and many other floating structures requiring sewage collection and treatment facilities. Average daily houseboat wastewater quantities are similar to those for normal land residences with a daily per capita flow of 75 gpd. Pumping all wastes to a shore sewer is the least expensive and most practical alternative wherever this is possible. Individual treatment devices including macerator - chlorinator toilets, incinerator toilets, septic tanks with soil absorption fields, and aerobic extended aeration units were considered.

■ Lear, Marks, and Schmincke, "Evaluation of Coliform Contribution by Pleasure Boats," CB-SRBP Technical Paper No. 10, Federal Water Pollution Control Administration, Middle Atlantic Region, Charlottesville, Va.,1966.

The report describes a sampling program and presents results and analyses of a study to determine the significance of fecal coliform contributed by pleasure boats. The sampling was conducted on the Miles River on the Eastern Shore of Maryland.

■ Mack, W.N., and D'Intri, F.M.,"Pollution of a Marina Area by Watercraft Use as Indicated by Coliform and Chemical Concentrations," East Lansing, Michigan: Michigan State University, Department of Microbiology, May, 1971.

Samples of water from a marina area in Michigan used by watercraft were tested for the number of coliform organisms. There was a slight increase in the coliform most probable number of organisms in the slips most frequently used by yachts. Outside sources of contamination probably added to the total number of organisms present in the area. Although an increase in the number of organisms was related to the presence of yachts in the marina, the concentration was far below the standard of total body contact as established by the Water Quality Standards for Michigan Intrastate Waters. Chemical analysis of water samples taken at the marina were within the normal limits for the specific area. Other factors contributing to the presence of the coliform organisms in this area were considered.

■ Rosenbusch, J.M.,"State-of-the-Art Report on Marine Sanitation Devices," Silver Spring, Maryland: Automation Industries,Inc., Vitro Labs Division, June 1973.

The report describes the problem of disposal of wastewater from recreational, commercial, and military vessels, with particular emphasis on recreational vessels. Contained in this report is a summary of marine sanitation devices wich are commercially available, and a breakdown of marine sanitation device research, development, test and evaluation programs being funded by the federal government and private agencies. An analysis is made of vessel limitations and constraints, and the suitability of the various marine sanitation device systems is compared to the vessel requirements. The conclusions note the major problems of wastewater treatment both onboard recreational, commercial, and military vessels and at dockside and the technical and economic factors that must be considered in the selection of a marine sanitation device.

■ Seabloom, Robert W.,"Bacteriological Effect of Small Boat Wastes on Small Harbors," Seattle, Washington: University of Washington, College of Engineering, July, 1969.

Since abatement of land-based sources of pollution is beginning to become a reality, pollution from vessels takes on a greater importance. One aspect of this problem is the overboard discharge of wastes from small recreational craft. Many states and other agencies have taken action to prevent toilet waste discharges from boats into recreational waters. Federal legislation is needed to provide an effective control of waste from small craft. Data are presented from a study of the small pleasure-craft pollution of two small bays in the state of Washington. In one, the influence of small boat wastes on the bacteriological quality of fresh water was clearly demonstrated. A review of the present methods for handling sewage from small craft concludes that while additional research is needed to improve the technology, the present systems are considered to be marginally adequate.

■ Underwater Storage, Inc., and Silver, Schwartz, Ltd.,"Collection, Underwater Storage, and Disposal of Pleasurecraft Waste: Feasibility of Connecting Sewage Holding Tanks On Board Recreational Watercraft to a Dockside Collection System and Storage in an Underwater Tank," Washington, D.C.: Federal Water Pollution Control Administration Water Pollution Control Research Series, DAST - 10, September, 1969.

A pilot plant was designed, constructed and operated to show the feasibility of providing a facility for the collection, storage, and disposal of waste from recreational watercraft. An on-board holding tank was installed in each of ten boats for total impoundment of all effluent and for the connection to a dockside sewage collection system through a quick-connect coupling. Each boat was provided with a pump, tank, and macerator. At dockside, each boat holding tank was pumped directly into a piped collection system. The project demonstrated that on-board storage of watercraft waste and subsequent discharge to an underwater storage tank was effective and economical. This project showed that the discharge of sewage from boats into rivers, lakes, waterways, and estuaries could be eliminated.

II Boating Related Impacts - Chemical

- Hare, Charles T., and Springer, Karl J., "Exhaust Emissions from Uncontrolled Vehicles and Related Equipment Using Internal Combustion Engines - Part 2: Outboard Motors," Southwest Research Institute, San Antonio, Texas, January, 1973.

Exhaust emissions from four 2-stroke outboard motors were measured before and after being bubbled through water, and the constituents measured were: CO, CO_2, NO, hydrocarbons, NO_x, O_2, and total aliphatic aldehydes and formaldehyde. The engines tested were a Chrysler 35 hp twin, a Mercury 65 hp in-line four, and OMC twins of 4 hp and 9.5 hp. The engines were operated on stationary test stands with power absorption by electric (eddy current) dynamometers driven from the propellor shafts. Pertinent operating data were recorded along with the emissions, and mass emissions computed from data gathered during this project are used in conjunction with available sales and usage data to estimate national emissions impact.

- Moore, Stephen F., et.al.,"Potential Biological Effects of Hypothetical Oil Discharges in the Atlantic Coast and the Gulf of Alaska," M.I.T. Sea Grant Publication 73-6: Cambridge, Massachusetts, 1974.

This analysis of the primary biological effect of potential offshore oil spills resulting from hypothetical oil production was commissioned by the Council on Environmental Quality as part of its studies on oil exploration and drilling on the Atlantic and Alaskan continental shelves. Qualitative predictions of physical, chemical, and biological effects of oil on different coastal habitats and natural communities are based on the probability of accidental spills, spill trajectories, and the behavior of oil in marine ecosystems. A spill's initial impacts depends on the amount, composition, and distribution of the oil, and the sensitivity of the ecosystem's species to it. To individual organisms, oil may be toxic or tainting by coating or hydrocarbon accumulation in tissues; alteration of the substrate by oil deposition may exclude species from their normal habitats. Persistence of the oil depends on the physical variables which control the degradation processes of evaporation, dissolution, microbial and chemical or light oxidation. Persistence rates in different habitat types are estimated from documented spills. Biological recovery times for species suffering 100% mortality vary with the species' dispersal strategies and fecundity; anadromous fish may also be vulnerable to oil. Habitat recovery times cannot be accurately predicted because of a lack of data on the recovery times of different species.

- Shuster, W.,"Control of Pollution from Outboard Engine Exhaust: A Reconnaissance Study," Troy, New York: Rensselaer Polytechnic Institite, Bio-Environmental Engineering Division, EPA Water Pollution Control Series, 15020 EPA, September, 1971.

A reconnaissance study has been made to determine the extent of pollution which results from the operation of a two-cycle outboard engine. Comparisons have been made of engine operation with and without a pollution control device attached. Studies have also been made of the biodegradability of the fuel and exhaust products. Tests made in a swimming tank with an untuned engine have shown that the quantity of fuel wasted as exhaust varied from about 7 percent of the volume of fuel used at high speeds, to over 30 percent at low speeds. When the Goggi pollution control device was installed, these quantities were intercepted and collected rather than discharged with the exhaust. Analysis at various depths indicated that nearly all products separated from water in a short time and collected on the surface. Various analytical techniques were studied. Both fuel and exhaust products are capable of sustaining microbial growth.

■ Walter, Robert A., "U.S. Coast Guard Pollution Abatement Program: A Preliminary Report on the Emissions Testing of Boat Diesel Engines," Cambridge, Massachusetts: U.S. Department of Transportation, Transportation Systems Center, November, 1973.

The exhaust emission concentrations from three GMC-71's and a Cummins VT-350 diesel engine were measured on a dynamometer as a function of engine load. The GMC-71 engines were newly rebuilt by the Coast Guard; the Cummins engine was in used condition. The exhaust emission concentrations were reduced to mass emissions by the carbon balance technique. Similar levels were obtained from the three rebuilt GMC-71 engines with type HV injectors.

III Boating Related Impacts - Physical

- Das, M.M., "Relative Effect of Waves Generated by Large Ships and Small Boats in Restricted Waterways," Berkeley, California: University of California, Berkeley, Hydraulic Engineering Lab, November, 1969.

The peak wave energy in a system of waves resulting from the passage of a ship is important in engineering problems such as bank erosion, the motion of moored vessels, and forces on fixed and floating docks. With respect to bank erosion, the question often asked is whether the single passage of a large ship is more damaging than numerous passages of small pleasurecraft. The study was conducted to determine the relative importance of the peak energy resulting from the passage of a cargo ship and a pleasure cruiser. The characteristics of the waves generated by these vessels moving at various speeds in deep and shallow water were determined from model studies. A numerical example is given in which prototype values of peak wave energy were predicted from the model data, and then ratios of the peak energies computed. The importance of ship speed is evident in these comparisons.

- Gustafson, F., "Supposed Toxicities of Marine Sediments. Beneficial Effects of Dredging Turbidity," World Dredging and Marine Construction, V.8, #13, pp. 44-52, December, 1972.

The ability of clay to remove materials out of the water column is considerable. The longer the period of suspension the greater will be the success of removal. Oils, pesticides, sewage pollutants (with the exception of nitrates), and metals are all stripped or scrubbed from the water by the clay sediments. As the clays fall and become bottom sediments, the materials which have been stripped out are almost completely isolated. The difference in concentrations of metals between sediment and water illustrates the adsorptive capacity of the sediments and proves their importance in the removal of these chemicals from the water. An experiment was designed to test the effectiveness and the permanence of the adsorption and the results show that resuspension of bay sediments caused an increased removal of the metals from the water. Pesticides and PCE followed the action of the metals. The short-time resuspension of sediments such as might occur during dredging or even during disposal in confirmed areas will not produce an excessive growth of algae. Results indicate that organic molecules are not liberated when resuspended in amounts sufficient to cause ecological concern. An experiment to determine if marine organisms could or would digest metals and pesticides from clay particles was conducted using clams. The results were not conclusive.

- Magrab, Edward B., "Establishment of Noise Criteria for Recreational Boats," Washington, D.C.: Catholic University of America, Department of Civil and Mechanical Engineering, July 20, 1973.

The noise emitted by recreational boats presents the following problems: noise pollution to by-standers, communication difficulties onboard, and permanent damage to an individual's hearing. A noise criterion must be determined first in order to solve these problems. A noise analysis of various common recreational boats and engines was conducted from measurements taken in the field. Standard test procedures for taking sound measurements exterior to and on-board recreational boats were established. The mean value of noise from large, small, and all motors were found to be 85.4, 80.2, and 82.9 dBA respectively. A noise level of 65 dBA is considered moderately noisy by most people. Therefore, most all motors emit an unacceptable level of noise to people in boating areas such as lakes, rivers, etc. The problem of communication among individuals on-board recreational boats may present a safety hazard in a fog situation where warnings of danger must be spoken or ships' whistles and fog signals must be heard. A high noise level such as 82.9 dBA over a long period of exposure may also be damaging to an individual's hearing. Standard test procedures have been established to measure the noise level emitted from recreational boats as a first step to help eliminate the above problems.

■ Wolman, M.G., "Problems Posed By Sediment Derived From Construction Activities in Maryland," Annapolis, Md.: Maryland Water Pollution Control Commission, January, 1964.

Bare land is subject to rapid erosion by rainfall and runoff. Because construction denudes the natural cover and exposes the soil beneath, the tonnage of sediment derived by erosion from an acre of ground under construction in developments and highways may exceed 20,000 to 40,000 times the amount eroded from farms and woodlands in an equivalent period of time. The amount of sediment eroded from the site as well as the amount which reaches the stream channel depend upon the coincidence in time of storms and exposure, the season of the year, the geology and topography of the site, the layout of the project, and the proximity of the site to a network of perennial streams. Deposition of sediment in stream channels may reduce channel capacity and materially alter the flora and fauna. Data are insufficient to assess the permanence of these effects. High sediment yields for periods of short duration fill small ponds and reservoirs to capacity. To date larger reservoirs and estuaries show less cumulative effects presumably due to storage in streams and valleys, to dispersal of development on the watersheds, and perhaps due also to the fact that records are more limited. Problems posed by sediment derived from construction in Maryland are local and of variable magnitude. Because techniques of demonstrated economic practicability, utilizing vegetation and structures, are available for reducing the quantity of sediment, if the sediment load now making its way to the streams of Maryland is to be reduced, effective ways of encouraging more widespread adoption of control practices must be developed.

IV Boating Related Impacts - General

■ Blumenthal, I.S., "Positive Pollution," Santa Monica, California: Rand Corporation, March, 1971.

The report is from talk on the results of an investigation in support of the conjecture that there should be something good about pollution. The subject is addressed with particular reference to marine recreation.

■ National Industrial Pollution Control Council, "Land and Water Pollution from Recreational Use," Washington, D.C.: National Industrial Pollution Control Council, December, 1971.

The report presents recommendations on the possibility and abatement of air and water pollution resulting from recreational equipment such as boats, camping equipment, snowmobiles, etc.

■ Pacific Northwest Water Lab, "Pacific Northwest Watercraft Pollution Study" and "Appendix," Corvallis, Oregon: Pacific Northwest Water Lab, February, 1967.

The purpose of the study was to determine the extent, seriousness, and causes of water pollution in the Pacific Northwest attributable to watercraft users; further, to determine what legislation and physical means are presently available to control this pollution; and what additional means and legislation are needed. All data were obtained from existing manuals, reports, and files; and by correspondence and personal interviews with personnel of various Federal, State, local governmental, and private agencies. The Appendix presents extensive information on the extent of waterways, recreational watercraft and supporting shore facilities commerce, commercial watercraft and supporting shore facilities, governmental watercraft and supporting shore facilities, and legislation and regulations.

■ U.S. Federal Water Pollution Control Administration, "Water Pollution Caused by the Operation of Vessels," Washington, D.C.: FWPC Administration, December, 1966.

The extent of the problem of pollution from vessels has been reviewed and evaluated, and recommendations for corrective and preventive action have been developed. All navigable waters of the United States have been considered in the study--coastal waters with their bays, sounds, and inlets and the myriad of rivers, lakes, and canals comprising the nation's major inland water resources. This report represents an initial assessment of the degree and magnitude of the problem which may be further refined by future studies. The great diversity in vessel size, type, usage, and operating conditions is recognized.

V Marina Management and Operations; Related Impacts

- Delaune, Kathryn M., "Proceedings of the Recreational Boating Seminar Held in Galveston, Texas, on December 17, 1971," Report on Sea Grant Program, College Station, Texas: Texas Engineering Experiment Station, Industrial Economics Research Division, January, 1972.

The leisure industry is the third largest in the nation. Of all water-related activities, recreational boating is one of the fastest moving. At the seminar in Galveston, marine insurance, marketing trends, maintenance, repairs and boating safety were discussed.

- Lyon, G.H., Tuthill, D.F., and Matthews, W.B., "Economic Analysis of Marinas in Maryland," (MP 679), College Park, Maryland: University of Maryland Agricultural Experiment Station, April, 1969.

The total investment in marinas in 1965 was $35 million for an average investment of $104,272 per marina. The land value of these marinas was $25.2 million, an average of $9,536 per acre. A relatively large number of marinas, 53, had gross incomes of less than $5000; 21 reported gross incomes of over $250,000. Forty-one marinas reported gross incomes of $100,000 to $250,000 in 1965. During the peak month of employment in 1965, marinas employed 2200 workers. In that year, marinas operated at about 88.6% of their full capacity. Overall, marina operators reported a strong demand for marina facilities. Operators in some areas reported keeping waiting lists of prospective customers. In other areas there were surplus facilities. Altogether, marina owners reported they needed 30% more slips than they had on hand in 1965. Marina owners indicated that they intended to expand their operations during the next 5 years. Seventeen limited service type marinas were studied to determine their costs, revenues, and net returns: average total costs for the 17 marinas amounted to $155.94 per slip annually; the average revenue was $167.53 per slip; and the return to management was only $11.59 per slip. Economies of size analysis was also made for limited service marinas.

- Nixon, S.W., Oviatt, C.A., and Northby, S.L., "Ecology of Small Boat Marinas," Rhode Island University Graduate School of Oceanography, 1973.

In Wickford Harbor, Rhode Island, a yacht marina area and a salt marsh cove were considered as ecological systems and compared to evaluate biological populations and magnitudes of production and respiration. Volume and flushing characteristics of both areas were similar. Analyses were made in each cove on marsh grass production, suspended particulate matter, phytoplankton, nutrients, bacteria, dissolved organics, copper levels, fish and sediments. Biomass and metabolism measurements were made on the fouling communities present on floats and pilings in the marina. Preliminary bioassays were performed with concentrations of outboard motor exhaust water on several species of estuarine organisms. Some additional comparative measurements were taken inside and outside other marinas located in Narragansett Bay. In most respects the marina cove and the marsh cove appeared to be not only similar, but also compatible, ecological systems.

■ U.S. Army Corps of Engineers, "Small-Boat Harbor, Mississippi River at Pepin, Wisconsin: Final Environmental Impact Statement," St. Paul, Minnesota: U.S. Army Engineer District, October, 1971.

The project provides remedial works to adequately protect from wave damage an existing harbor on Lake Pepin at Pepin, Pepin County, Wisconsin. The harbor will then be more usable and easier to maintain. In addition, docking facilities can be expanded and improved without fear of further damage due to wave action. Construction will cause a temporary increase in turbidity which would have minimum impact on the water quality. No additional adverse impacts upon fish and wildlife resources will result from the project.

VI Recreational Planning

■ Altouney, E.G., Crampon, L.J., and Willeke, G.E., "Recreation and Fishery Values in the San Francisco Bay and Delta," Menlo Park, California: Stanford Research Institute, October 7, 1966.

The contents of this report are: estimates of recreation use other than hunting and fishing; approach to estimates of recreation use; potential demand of 11-county area residents; potential demand of all other California residents; potential demand of all other U.S. residents; total potential demand of all groups; total expected use in the study area; present recreation use by activity, region, and type of participant; breakdown of projections by activity, region, and type of participant; sport fishing; commercial fishing; waterfowl hunting; method of computation; summary of benefits.

■ Bishop, D.W. and Aukerman, R., "Water Quality Criteria for Selected Recreational Uses," Urbana, Illinois: Water Resources Center, University of Illinois, September, 1970.

Four types of outdoor recreationists were investigated to determine whether they differed in their attitudes, beliefs, and behavior regarding various water characteristics at Central Illinois water-based recreation sites. Using an attitude model derived from social-psychological research, the recreationists' attitudes toward the sites were estimated from their attitudes and beliefs about water characteristics. The site attitudes were regarded as indicators of the quality of the respondents' recreation experience resulting from characteristics of the water. The major analyses were comparisons of the recreationist groups' perceptions of the water, attitudes toward water characteristics, the site attitudes held because of water characteristics, reports of decreased site use because of water characteristics, and reports of probable termination of site use because of water charactertistics. The results indicated that the four types of recreationists differed in their perceptions of the water, attitudes toward water characteristics, site attitudes, and the reported water characteristics that had caused or might cause decreased site use. In addition to these group differences, there were strong individual differences within the various groups. Site attitudes were not highly related to reported behavior.

■ Ditton, Robert B., "The Social and Economic Significance of Recreation Activities in the Marine Environment," Sea Grant Technical Report #11, Green Bay, Wisconsin: University of Wisconsin, January, 1972.

Individuals, adjacent shoreland owners, businessmen, polluters, etc., must begin to assume responsibility for the sustained yield of the coastal zones if society is to realize the full social and economic significance of recreational activities in the marine environment. While sustained yield is a socioeconomic concept promulgated by foresters concerned with perpetual production of high-quality timber, resource managers have since recognized that it has application to all of our renewable and nonrenewable resources. Because of the undeniable relationship of leisure-man and environment, sustained yield can and should be applied in the recreational development of the marine environment, our goal being continuous availability of satisfying water recreation while sustaining the nonrenewable natural coastal zone ecosystem.

■ Ditton, Robert and Goodale, T., "Marine Recreational Uses of Green Bay: A Survey of Human Behavior and Attitude Patterns.," Madison, Wisconsin: University of Wisconsin Sea Grant Program, December, 1972.

A survey of 2,174 heads of households in the Green Bay area showed that over two thirds of those interviewed participated one or more times in fishing, swimming or boating during the twelve months prior to the survey. Frequency of participation was highest for fishermen and lowest for boaters. The popularity of the recreation facilities of Green Bay is given. A direct relationship between water quality and recreational use is clearly demonstrated. The relationship between education, place of residence, and participation in marine recreation is discussed. Opinions on bay water quality problems are surveyed. Group (fishermen, boaters, swimmers, and non-participants) comparisons are made.

■ Ditton, Robert, and Goodale, T., "Recreational Uses of Green Bay: Bay/ Non-Bay Users Compared," in Proceedings of Conference on Great Lakes Research, (15th), April, 1972, pp. 729-736.

The paper identifies the proportion of a representative sample of heads of households who used Green Bay for recreation and relates their activity and location to their perception of Bay water characteristics. Variables observed to differ between groups included place of residence, years of schooling, willingness to pay for water quality improvement, water quality and physical characteristics described as most bothersome and reasons for not participating more. The data suggests Bay use was related to the participant's perceptions of the Bay's water quality and physical characteristics. Compared to non-Bay users, Bay users were more troubled by winds, water temperature and cloudiness; were more deterred from further participation by 'dirtywater' and were inclined to allocate more money for water quality improvement.

■ Ditton, Robert, and Goodale, T., "Water Quality Perception and the Recreational Uses of Green Bay, Lake Michigan," in Water Resources Research, Vol. 9, No. 3, June, 1973, pp. 569-579.

How people perceive Green Bay as a recreation resource, how perceptions differed between groups, and how these perceptions related to recreation use patterns, are identified. Whereas seven of ten household heads interviewed participated in boating, or swimming, only three of the ten used Green Bay during the preceding twelve months, indicating that Green Bay was not a focal point of water-based recreation among residents of the five-countystudy area. Chi square test groups differed significantly on most comparisons when used to describe the Bay and its most bothersome physical and water quality characteristics. Generally, participants and those who use the Bay were less apt to cite unpleasant smell and dead fish as major problems and more apt to cite such problems as winds, waves, and cloudiness. Comparisons between three user groups (fishermen, boaters, and swimmers) indicated swimmers and boaters differed most in their perception of the Bay and its troublesome characteristics, with fishermen occupying a position between to two groups.

■ Francis, J.D., and Busch, L., "Water Recreational Activities in New York State and the Effect on Associated Industries," Ithaca: New York State College of Agriculture and Life Sciences, August, 1973.

Trends in recreational boating and its associated industries--the boat building and repair industry, the retail boat dealerships, and the marina industry--are discussed. Sports fishing and its associated industries are the major activity examined.

■ Mechalas, B.J., Hekimian, K.K., Schinazi, L.A., and Dudley, R.H., "Water Quality Criteria Data Book - Vol. 4: An Investigation into Recreational Water Quality," El Monte, California: Envirogenics Co., April, 1972.

A new technique has been developed for establishing firm criteria for health risks associated with recreational water bodies. The basis of the method is a mathematical treatment of medical dose-response data in conjunction with the probability of exposure over a period of time to a given level of the potentially harmful factor, such that a quantitative risk can be assigned to the recreational activity. Once a public health jurisdiction has established an acceptable level of risk, curves produced by electronic data processing equipment can be used to ascertain whether a particular water should be open to the public.

■ Megli, L.D., Long, W.H., Gamble, H.B., "An Analysis of the Relationship Between Stream Water Quality and Regional Income Generated by Water-Oriented Recreation," Research Publication Vol. 69, University Park, Pennsylvania: Penn State University Institute for Research and Land and Water Resources, December, 1971.

The hypothesis tested is: the recreational use of streams and, therefore, the amount of regional income generated by recreation-related expenditures are directly related to stream water quality in the area. Data were gathered about in-stream water quality and recreational use of streams for thirty areas of Pennsylvania. Water quality indicators were dissolved oxygen content, pH value, and the temperature of the stream water. Expenditures by sector within the local area were converted to estimates of regional income generated thorugh the use of sectoral regional income multipliers adapted from an inter-industry study of a Pennsylvania county. The results indicated a positive correlation between in-stream water quality and the amount of regional income generated by recreation related expenditures.

■ Menchik, M.D., "Outdoor Recreational Management: A Mathematical Model," Madison, Wisconsin: University of Wisconsin Institute for Environmental Studies, August, 1973.

This paper formulates and evaluates outdoor recreational management policies. The mathematical programming model developed allocates the use of a given system of outdoor recreational facilities so as to maximize a measure of user satisfaction without exceeding site carrying capacities.

■ Shane, R.M., Day, H.J., Frenkil, S.M., Ho, P.H.P., "Riverine Recreational Development: Mathematical Modelling," Pittsburgh, Pennsylvania: Carnegie Mellon University, Department of Civil Engineering, September, 1973.

A computer simulation model is developed to make water quality projections for planning urban recreation. One of the goals of this research is to evaluate the recreational potential of the Allegheny River, particularly that portion closest to the city of Pittsburgh. The present water quality of the Allegheny River is suitable for boating and general fishing; but it is not suitable for swimming or active game fishing at this time.

■ Sorenson, Jens C., "A Framework for Identification and Control of Resource Degradation and Conflict in the Multiple Use of the Coastal Zone," Berkeley, California: Department of Landscape Architecture, College of Environmental Design, University of California, 1971.

This thesis is directed to the issues of (1) resolution of conflict among competing uses of resources in the coastal zone, and (2) control of resource degradation. It is organized into five parts: the first part, a brief discussion of resource conflict and degradation, serves to background the idea of developing the framework procedure described in parts two and three (II - Development of an Impact System Framework, III - The Framework Components). Applications of the framework, both as observed and foreseen, are outlined in part four. The concluding portion cites future tasks for the improvement of the procedure. Several matrices are developed; matrix B analyzes the impacts of recreational activities on environmental, socioeconomic, aesthetic, and health and safety factors. The possible adverse impacts (initial condition, consequent condition, and effect) are balanced against corrective actions/control mechanisms.

■ Tilley, William S., "Planning for North Carolina's Coastal Inlets: An Analysis of the Present Process and Recommendations for the Future," Report No. 73-4, Raleigh, North Carolina: North Carolina State University, Center for Marine and Coastal Studies, September 12, 1973.

This study evaluates the present decision-making process for problems involving coastal inlets in North Carolina. The natural processes at inlets are reviewed and man's relationship with inlets explained. The present government decision process is defined by identifying the participants, their policies, objectives and authority, the factors considered, operation of the process in practice and the part the process itself plays in the result. The process is evaluated by examining government and public satisfaction and by comparing the present process to a rational planning model. Conclusions about the needs of the present process and recommendations for improvements are presented.

■ Tybout, Richard A., "Public Investment Criteria for Water Oriented Recreation in the Lake Erie Basin," Columbus, Ohio: Ohio State University Water Resources Center, December, 1972.

The research results of an attempt to correct several basic flaws in the economic theory relevant to pricing pollution and other negative externalities are presented. The validity of the theorem concerning the ownership of a polluting factor and its effect on the allocation of resources is criticized. Comprehensive measurement of the demand for water-based recreation is discussed. Three important effects which must be reflected in shift parameters were noted, and a theoretical model for shift analysis within an econometric framework was developed.

VII Recreational Carrying Capacity; Zoning and Other Regulatory Mechanisms

■ Jaakson, Reiner, "Planning for the Capacity of Lakes to Accomodate Water-Oriented Recreation," in Plan, Vol. 10, No. 3, 1970.

All planning and development of natural resources must be based on the concepts that a resource is not inexhaustible, and that there is a close relationship between the intensity of use of the resource, and the quality of use. A lake as a natural resource falls clearly into this classification. The amount of recreation that it can withstand should be calculated to achieve two aims: 1) to protect the natural environment of the lake; and 2) to allow the recreation milieu to maintain a density of use and activity which will be considered as attractive by the recreationists.

The problem, therefore, of resource development is, distinctly, over use. With an increase of the number of recreationists a larger segment of demand will be satisfied, but only at the expense of lowering the quality of the recreation experience. The end result often is a rejection, by the recreationists, of the resource.

The recreation capacity concept may be used by planners as a guide-line on which the land use planning of lakes may be based, and on which cottage subdivision and the public sector of recreation may be better evaluated. The capacity concept is not a formula or a blueprint, but rather an underlying principle on which some land use planning considerations may be made.

■ Jaakson, Reiner, "Recreation Zoning and Lake Planning," in Town Planning Review, Vol. 43, No. 1, January, 1972, Liverpool, United Kingdom: Liverpool University Press.

This paper presents a framework which incorporates five shoreline land-use zones and three water-surface zones into a conceptual model of lake planning. The components of this model, the zones, their meaning, nomenclature and suggestions for delineation, are a general guide; it is the underlying thought processes, and their broad implications to lake planning, which embody the key concepts. The strategy suggested for lake planning for recreation is that zoning, as one facet of planning, must deal both with the development of the shoreline, as well as with the control of activities on the water. Proposals that are attendant to recreation zoning have been woven into the main theme, and include, in some detail, criteria for the design of holiday home subdivisions, and, in a more general way, notions on public access and public use of lakes. The Canadian, and particularly the Ontario, socio-economic and physical setting of recreation lakes has been presented as an example of the implementation of the zoning and planning concepts.

■ Jaakson, Reiner, "Zoning to Regulate On-Water Recreation," in Land Economics, Vol. XLVII, No.4, November, 1971, Madison, Wisconsin: University of Wisconsin Press.

To meet the need for more effectice control of on-water recreation, it has been argued that activity zones can be delineated by grouping recreation pursuits into categories which exhibit similar density requirements and speed characteristics. It has been further argued that, by means of activity zones, incompatible recreation pursuits can be segregated and their conflict and competition minimized. Measures to protect the ecosystem of a lake from the adverse effects of recreation activity have been presented and have been incorporated into the concept of on-water spatial organization. Three activity zones have been proposed: a Shoreline Activity Zone, an Open Water Zone, and a Wildlife Zone. The performance characteristics of popular recreation activities, and their relationship to the biotic communities of the lake, constitute the underlying theme which molds the basic zoning concept.

The organization of on-water activities within a zoning framework which attempts to facilitate the simultaneous carrying out of a number of recreation pursuits is a general model which demands substantial modification in the process of its application to specific waterbodies. Legislative and administrative constraints may severely restrict the effective implementation of the model; the distinct morphology or ecology of different waterbodies may command a unique arrangement of the zones; adjustments in the model on a temporal basis may also be necessary, as a response to time-variations in recreation activity. It is believed, however, that the model presents a plausible concept for rational planning of the recreation utilization of lakes and, with necessary alterations, of waterbodies in general.

■ O'Connor, Dennis M., "Final Report of the Task Force on Dade County Waterways Regulation," Sea Grant Special Bulletin #12, Miami, Florida: Miami University Sea Grant Institutional Program, February, 1973.

The report concerns the need for planning and managerial expertise at the local level in the management and regulation of waterways. Specific recommendations are made on ; watercraft ownership and use; pollution from watercraft; shoreline facilities;enhancement of shoreline use. Appendices contain documentation on Federal, State and local laws and ordinances pertaining to county waterways; recent federal legislation pertinent to waterways management; and authority under State Law for county action on waterways.

VIII Estuarine Processes - General

Clark, John C., Coastal Ecosystems, Washington, D.C.: The Conservation Foundation, 1974.

Planning requires a system of identification and classification of general areas of environmental concern. These are the areas within which human activities must be controlled, not necessarily prohibited, to protect the environment. Smaller areas that are especially critical ecologically--vital areas--are to be designated for complete protection within areas of concern. Estuaries and their surrounding tidelands and wetlands are areas of environmental concern. Eleven principles derived from ecology are presented. They underlie the major Management Principles developed relative to ecosystem integrity, drainage, drainageway buffers, wetlands and tidelands, storage, and energy, and the Management Rules developed relative to drainageways, basin circulation, nutrient supply, nitrogen, turbidity, temperature, oxygen, salinity, and runoff contamination. Because both land and water use controls are necessary for best achievable ecosystem function, which usually means as near to the natural condition as possible, it is necessary to regulate both the location and the design of projects in shoreland and coastal water provinces. Also, many types of human activities must be controlled to some degree. In addition, the construction of many types of projects and their operations will have to conform to certain performance standards. The conclusion reached is that "Whatever its specific goals may be, an environmental management program must embrace whole ecosystems. Any attempt to manage separately one of the many interdependent components of a complex ecosystem will very likely fail. So would any attempt to control any one source of environmental disturbance to the system without controlling others....Development adjacent to estuarine waters will require exceptionally vigorous management attention." (Clark, p. ix)

IX Chesapeake Bay - Background Information

- Maryland Department of State Planning, "Integrity of the Chesapeake Bay," Annapolis: Department of State Planning, July, 1972.

  This document represents a summary of the major findings and conclusions contained in the "Maryland Chesapeake Bay Study," a report prepared for the Chesapeake Bay Interagency Planning Committee. The Bay Study represents the first comprehensive Maryland Chesapeake Bay inventory of natural resources and economic development problems with suggested mechanisms for management planning. This Summary Report of the Bay Study is divided into 3 major sections. The first describes the general characteristics of the Chesapeake Bay including its physical and natural characteristics, its commercial value, economic viability, and the population within the Bay region. Eight major problems which have ecological, social, econmic and planning and management significance to the Bay, and goals useful in ameliorating the problems are discussed in the second major section of this report. The final section outlines the elements needed to prepare an effective management plan for the Chesapeake Bay. Alternative management institutions which would respond most effectively to the Bay problems are also discussed.

- Mihursky, J.A., McErlean, A.J., Kennedy, V.S., and Roosenbury, W.H., "Regional Planning and the Chesapeake Bay Environment: An Ecological Approach," presented at New England Coastal Zone Management Conference, Durham, New Hampshire, April 28-29, 1970, Prince Frederick, Maryland: Natural Resources Field Station, University of Maryland.

  A heavy outpouring of funds, manpower, and coordinated research and management effort in every sector, both public and private, is required to respond to the environmental needs of society. The Chesapeake Bay system is used as an example of an easily definable and describable area from the heavily industrialized and populated northeast coast of the United States. Maryland's economy, style of life, and quality of life are almost entirely dependent upon the specific nature of the Bay and its environmental characteristics and balance. Some examples are presented of ecological consequences of certain decisions which resulted in environmental changes to the system: the proposed widening and deepening of the Chesapeake and Delaware Canal will result in a loss of freshwater flow and possible increased salinities; steam electric stations are rapidly being located in coastal regions.

X Boating Data and Operations

■ Alexandria Drafting Co., comp., Salt Water Sport Fishing and Boating in Maryland, Alexandria, Virginia: Alexandria Drafting Co., n.d.

This publication includes complete Tide Tables, Aids to Navigation, and the National Ocean Survey Nautical Chart Index. Also featured is a complete listing of Maryland's many marinas, with chart locations for each. The habits and habitats of many of Maryland's most popular game and 'table' fish are described in an article by Wheeler Johnson. Supplementing the text, the fisherman may reference numerous illustrations showing favorite fishing knots, loops, and terminal tackle. Additional pages are devoted to the Salt Water Sport Fishing Calendar, to listing charterboat captains and how to contact them, and to listing complete results of the 1971 Maryland Citation Award Program, with the anglers' names, dates, and locations of their catch. Probably the single most impressive feature is the 55-page array of multicolor charts, which cover Maryland's Atlantic Coast and offshore fishing waters, and 6 pages of special charts that include the entire Chesapeake Bay, from the Chesapeake and Delaware Canal to the Virginia Capes. These charts identify natural landmarks, water depths, channels, oyster bars, danger areas, lights, buoys, wrecks, and even bottom quality. Highways, access roads, campgrounds, fishing streams, public clamming areas, and public beaches are just a few of the points of interest marked with descriptive symbols from the legend. Each chart pinpoints fishing hotspots, what fish frequent these areas, and when they are most likely to be caught. Of general interest are articles which relate diverse topics from Sport Crabbing in Maryland to the history and activities of the Maryland Marine Police.

■ U.S. Department of Transportation - U.S. Coast Guard, "Boating Statistics 1973," CG-357.

Statistics on boat numbering registration, boating accidents, and certain related activities for the U.S. for the calendar year 1973 are presented in this report. The boat numbering statistics were compiled from official reports received from the 47 states, the Virgin Islands, Puerto Rico, and Guam, which have federally approved boat numbering systems, and from the Coast Guard numbering records for other jurisdictions which do not yet have federally approved systems. The accident statistics were extracted from copies of Boating Accident reports submitted to those jurisdictions with approved numbering systems and forwarded to the Coast Guard; from reports submitted directly to the Coast Guard in those jurisdictions without an approved numbering system; and from reports of Coast Guard investigations of fatal boating accidents that occurred on waters under joint or Federal jurisdiction, and the high seas.

■ Wain, Sidney J. Inc., Waterway Guide '74 Featuring Chesapeake Bay, Vol. 27, No. 2, 1974.

The Guide is a useful data book for recreational boaters, providing charts, tide tables, tidal currents, and lists of shore facilities, as well as information on anchoring, bridges, vital Coast Guard phone numbers, hazards, history of the area, shellfish, weather, and winds. The Chesapeake Bay region is divided into 5 sections: the Upper Eastern Shore - quiet unobtrusive wealth, gentleman farmers, gracious old-style ways, tranquil villages;

the Upper Western Shore - with a heavy concentration of boats, much of the Bay's industry, some of its largest cities; Potomac River - winding water road to the nation's capital and dividing line between Maryland and Virginia, each with its own shore and its own particular style; the Lower Eastern Shore - remote and quiet, with islands and towns largely unaffected by passage of the years; the Lower Western Shore - deep, wide rivers, leisurely pace, culminating in the hubbub of Hampton Roads.

■ Watts, Oswald M., ed. consultant, Reed's Nautical Almanac and Tide Tables for 1974, Thomas Reed Publications Ltd., 1974.

Major topics covered in the Almanac are: navigation and nautical astronomy and radio aids to navigation; safety, distress and rescue, collisions; tides and tidal currents; visual navigational aids. Tidal currents in Chesapeake Bay are mapped, and tables of high and low water times and heights at Baltimore and Washington, D.C. are shown, as well as a chart of tidal differences on each port. Visual navigational aids are listed for each state.

APPENDICES

A. John Clark: "Potential Ecological Effects Associated with Boating and Support Facilities

B. William A. Niering: "Biological Effects of Motorized Boating on the Tidal Marsh Estuarine Ecosystem."

C. Maps: Environmental Constraints

APPENDIX A

Potential Ecological Effects Associated with Boating and Support Facilities

John Clark*

In recent years, agencies of local, state, and Federal governments have expended increasing amounts of effort in the protection of estuarine resources. Although it is not always explicit, these efforts have as a common goal the preservation of ecosystems; that is, an attempt to control the activities of mankind so as to alter the essential components of ecosystems. Out of this effort has arisen an understanding of adverse environmental effects (or impacts) that arise from damaging disturbances to natural estuarine systems, (estuary referring to protected brackish water bodies--bays, creeks, lagoons, tidal rivers and so forth). It is now understood that boating activity has the potential for causing numerous disturbances that can significantly degrade ecosystems and endanger the productivity of estuarine resources, particularly in confined, shallow waters.

ECOSYSTEM COMPONENTS

To predict adverse effects, it is necessary to consider the points of vulnerability of the estuarine ecosystem. This is done by separately studying each of the major components of the system, as discussed below:

Water Circulation

The combined influence of fresh water flow, tidal action, wind, and oceanic forces results in the natural pattern of water movement, or circulaton, found in each estuarine water body. Circulation of water transports nutrients, propels plankton, distributes the tiny young stages of fish and shellfish, flushes the wastes from animal and plant life cleanses the system of pollutants, controls salinity, mixes the water, and performs other useful work.

Any activity that significatly alters the natural pattern of circulation must be presumed to be adverse. Major disturbances of the natural circulation pattern may be caused by boating or construction of boating or navigation facilities:

1) Altering inlets and passes either by restricting them with bridges, causeways, or bulkheads, or by opening them by dredging.

2) Water flow blockage caused by spoil banks (deposits of dredged material).

3) Changing water flow by realignment, deepening or widening of channels.

4) Alteration of water flow patterns caused by encroachment of piers of fills into coastal waters.

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*Environmental Guidance Group, Washington, D. C.

be used as effectively as possible to avoid the discharge of unnatural amounts and types of growth stimulating nutrients, particularly nitrogenous wastes, into coastal waters.

Vital Habitat Areas

Many components of the coastal ecosystem are of such importance to certain species or to the functioning of the entire ecosystem that they need special protection from alteration and protection from pollution and other external sources of disturbances.

Fixed vital areas are readily located, surveyed and mapped, and remain constant in location. Transient vital areas, most often water masses of special ecological value, shift position with the wind, tide, river inflow, and so forth.

Vegetated tidelands: Paramount among the vital areas are the vegetated tidelands (tidal marshes). They serve as the vehicle for storage and transfer of nutrients into the coastal waters to provide basic nutrient for the estuarine food web. Tidelands vegetation removes toxic materials, excess nutrients, and sediments from estuarine waters and services to stabilize estuarine shorelines, prevent erosion, and slow the surge of flood waters. Its vitality depends upon exposure to tidal flushing, and upon the freshwater inflow. Structures and excavations--bulkheads, canals, foundations--which alter water flow are adverse. And, of course, vegetated tidelands should not be removed, obliterated, or reduced.

Wetlands: In the profile of the coastal landscape, wetlands are the areas above mean high tide mark and below the yearly high storm mark. They are naturally vegetated with wet-soil plants--a combination of salt-tolerant types of grasses and rushes often grading into typical fresh water marsh plants inland. Wetlands serve many of the same functions as the vegetated tidelands in cleansing runoff waters and regulating their flow, in taking up, converting, storing, and supplying basic nutrient to the coastal ecosystem, and in storm and erosion protection. They also provide essential habitats for various coastal birds and mammals.

Grass Beds: Submerged grass beds are important elements of the estuarine ecosystem, and in storm and erosion protection. They may supply food to grazing animals, provide detrital food to the water, add oxygen (during daylight hours), and stabilize bottom sediments. They are nursery areas for young fishes and crustaceans and, in general, attract an abundance and diversity of life. They are vulnerable to many types of pollution. Turbidity from silt and eutrophication screens out light and prevents growth of the grass. Fine sediments (mud) create unstable bottom conditions in which the grasses cannot anchor their roots. Also boat traffic through grass beds may compound the pollution problem by stirring up sediments or reduce the beds by cutting off the plants

The relevant constraint is to avoid significant change in the natural pattern of water flow by controlling structures and excavations in the water basin. The ecological disturbance potential increases as the water body becomes smaller or as flushing rate drops (Clark, 1974).

Sedimentation

The accumulation of sediments on the bottom of an estuarine basin results in shoaling of the basin and has adverse effects on water quality, circulation, and general ecosystem function. Fine sediments on the bottom trap pollutants and when resuspended by wind, currents, or boat traffic cause oxygen depletion, turbidity, and release of toxic substances and obnoxious gases. A heavy layer of fine sediment prevents occupancy by the normal bottom fauna and the rooting of sea grasses.

To prevent sedimentation and its secondary effects of turbidity and so forth, there should be controls on: 1)land clearing in the estuarine watershed, 2)dredging in and around coastal water basins, and, 3)the size, speed, and routing of boat traffic. Fine sediments (less than about 0.1 in. diam.) are of particular concern.

Oxygen

Of the various gases that are found dissolved in coastal waters, oxygen is of the most obvious importance to fish and other animal life. For animal life to be adequately supported, coastal waters need a high concentration of oxygen--Federal guidelines suggest 6.0 ppm and require a minimum of 4.0 ppm (four parts of dissolved oxygen per million of water, by weight) unless concentrations are naturally lower.

Oxygen may fall to unhealthy levels where boat sewage and other wastes with high BOD (biochemical oxygen demand) pollute coastal waters and induce high bacterial action that is particularly serious in the smallest, shallowest water bodies with poor flushing. The bacteria multiply rapidly to reach enormous abundance and deplete the water of oxygen faster than it can be replaced by either plants or the atmosphere.

Oxygen may be artificially depressed to dangerously low levels in deep box-cut canals around marinas where poor circulation prevents adequate flushing and where fine sediments accumulate--it was estimated that a half pound of organic wastes per day (for example, grass clippings) would contaminate a 100-foot length of canal reducing oxygen from 4.5 to 3.8 ppm (in southwest Florida).

It is most necessary to include dissolved oxygen controls in the coastal management program. A specific goal should be to maintain the natural oxygen environment--one that will normally be optimum considerably above 4 ppm.

Turbidity

Sunlight must be able to penetrate the water to foster the growth of both the bottom plants, such as seagrasses, and the suspended algae (or phytoplankton). Increased turbidity from the addition of suspended matter to the water reduces light penetration and has a negative effect on plant growth.

Increased turbidity may be caused by excavation in estuarine water basins, by the discharge of eroded soil with shoreland and runoff, or by boats or wind stirring up bottom sediments. Other increases are caused by excess nutrients derived from land runoff, sewage, or other discharges which stimulate algal growth and lead to clouding of the water.

Coastal waters have a natural content of suspended organic and inorganic matter and a turbidity that varies with the seasons and with irregular environmental changes, such as freshets, winds, and plankton blooms. Consequently, controls should not prescribe one base turbidity value but rather should permit continuance of the pattern of natural variation that characterizes the ecosystem. Specification of "existing natural amount", for any particular area or time, is so difficult a statistical problem that it would appear more practical to eliminate the source than to regulate the amount of discharge.

Salinity

Salinity throughout the ecosystem fluctuates with the amount of dilution by river inflow and by the extent of evaporation. There is a gradient in salt content that starts with high values in open waters, decreases inward through the estuary, and drops to zero at some distance up in the tributary tidal streams.

Some coastal species tolerate a wide range of salinities, while others require a narrow range to live and to reproduce successfully. Some require different salinities at different phases of their life cycle, such as are provided by regular seasonal rhythms in the amount of runoff.

As with other controlling environmental factors, coastal species have evolved over the years in harmony with their changing salinity environment and have adapted to the pattern of natural variation. In the absence of contrary evidence, it must be presumed that this natural, changeable, salinity regime provides for the optimum functioning of the coastal ecosystem.

The appropriate management practice is to avoid any significant change from the natural salinity regime by maintaining the natural patterns of water circulation. Anything that affects the circulation of confined water bodies and the normal supply and mixing of fresh and salt water can disturb salinity patterns. Any change over ten per cent of pre-existing conditions is considered adverse (Veri, et. al. 1973).

Toxic Substances

Boat and marine discharges are sources of a variety of toxic substances that pollute coastal ecosystems such as heavy metals, chemical wastes, and oil.

The emerging Federal policy is to eliminate the discharge of all harmful substances into the nation's waters. This policy is most easily applied to activities that produce and release wastes through outfall pipes. It is far more difficult to apply to boating activities that contaminate the water in a broader pattern of discharge. Pollution of estuarine waters by toxic substances will be controlled mostly by an evolving State and Federal management program.

Nutrient Supply

The animal life of the ecosystem is supported by vegetation including large plants, floating microplants (collectively, "phytoplankton"), and bottom growing microplants. The plants are nourished by minierals dissolved in the water, particularly compounds of nitrogen (nitrates, ammonia) and phosphorous (phosphates). This nutrient is provided from within the ecosystem through a continuous biochemical storage-release-cycling-restorage system. Nutrient continuously trickles out of the system by various processes and is replaced by minerals in the inflow of land runoff and from other sources.

Animal life is partly nourished by marsh grass and other leaves that decay rapidly into small particles (detritus). These particles, and the colonies of microscopic life on them, are eaten by a wide variety of estuarine species; for example, shrimps, some fishes, and a myriad of small crustaceans that serve as forage for birds and predatory fishes. Disturbances that decrease the natural supply of nutrients below the optimum level are harmful to coastal ecosystems. All components of the ecosystem, such as marshes, that supply natural nutrients, convert them to useful form, or provide for their flow to and within the ecosystem need protection from adverse change.

Eutrophication

An excessive supply of nutrient chemicals leads to eutrophication (over-fertilization) of estuaries, an unbalancing of the natural species mix of the ecosystem, and general degradation of water quality. Rapid "blooms" of phytoplankton lead to wide swings in oxygen concentrations that are ecologically adverse and often are followed by their mass death and decay. Waters may become turbid, estuarine bottoms fouled, and oxygen depleted. Particularly adverse are nitrogenous chemicals because these are the nutrients most responsible for triggering phytoplankton "blooms" in estuarine waters. Over-fertilization encourages sea nettles and other nuisance species.

Chemicals that cause eutrophication originate mostly with sewage effluent or resuspended sediments.

As with other ecosystem disturbances, the role of boating is normally minor and the major sources are industrial and domestic wastes, and contamination by fertilizers in land runoff water. These sources must be controlled to protect estuarine ecosystems. There are Federal and State controls on discharges from boats and these should

Breeding and Nursery Areas: Many coastal species concentrate in specifically defined estuarine areas for breeding. Their young may then settle into special areas called nursery areas when they are several weeks old, areas where the young prosper because the right food is available, predators are in the least abundance, and other conditions are most suitable for their survival. Nursery areas may be tidal creeks, shallows, grass beds, or open flats. Breeding and nursery areas should be protected from environmental disturbance.

Feeding Areas: Many of the wading birds have definite and readily definable feeding areas in marshes or coves and fishes may feed in certain areas, such as shellfish beds or grass beds--vital habitat areas previously identified for protection. In addition, there are not-so-well defined places that are important feeding areas, such as inlets and passes or persistent tiderips where baitfish may gather to feed and gamefish come to prey. Adverse alteration of water circulation or degradation of water quality interferes with these feeding areas.

Shellfish Beds: Oysters and other valuable shellfish are usually found concentrated in certain flats, banks, bars, or reefs. Oyster beds harbor large communities of other life--crustaceans, worms, etc.--that make them rich feeding areas for many fishes, birds and mammals in shallow estuaries. Also, large populations of oysters or clams filter the water, removing suspended matter and reducing turbidity. Many ecosystem disturbances are harmful to shellfish. Silt laden waters are a harsh environment for their planktonic young states and layers of mud are an unsuitable bottom for many of them. Even a thin veneer of silt over otherwise clean surfaces may prevent oyster larvae from attaching. Shellfish beds are often buried or dismantled by dredging. Bacteria from sewage may be concentrated in shellfish tissue making it dangerous to eat.

IMPACT VULNERABILITY

From the preceding discussion it is apparent that there are particular characteristics of aquatic ecosystems that govern their capacity to absorb impacts. Two of these might be specified in quantitative terms: 1)contamination potential, the probability that pollutants discharged into any water body will accumulate to damaging levels; 2)turbidity potential, the probability that sediments deposited on the bottom will be resuspended by the action of boats (or natural forces) to cause turbidity or eutrophication.

The contamination potential of a water body is a function of its capacity (length, width, and depth) and the rate of exchange (flushing) of its waters. We suggest expressing this in convenient mathematical form as follows (values are illustrative only).

$$\text{Contamination Potential Index} = \frac{(\text{depth}) \times (\text{width})}{1000} \times \text{Flushing rate}$$

(where depth and width are in feet and flushing rate in days)

A contamination index of 10 or less denotes a water body of low capacity that is especially sensitive to contamination. An index of 100 or more indicates a water body of higher capacity that is less sensitive. An index of 50 indicates a water body of intermediate capacity, and so forth.

The <u>turbidity potential</u> of a water body is a function of its depth (propwash effect), the thickness of the layer of sediments over firm bottom, and the fineness of those sediments. This can be expressed in mathematical form as follows (values are illustrative):

$$\frac{\text{(Potential)}}{\text{Turbidity Index}} = \text{depth} \times \text{particle size} \times \frac{1}{\text{layer depth}}$$

(where water body depth is in inches, particle size or fineness is in millimeters, and layer depth of sediments is in inches)

An index of less than 10 indicates a high potential for the resuspension of sediments by boat propwash while one of 100 indicates a lower potential for resuspension. A value of 50 indicates an intermediate potential. This index attempts to interpret into a practical format the guidance standards set forth by the Federal Water Quality Agency (NTAC report, 1968) that recommend no discharge of substances that will result in turbidity levels deleterious to biota. Also these standards state that turbidity levels less than a Secchi disc reading of 1 meter (3 feet) or equivalent in Jackson Turbidity Units (JTU) "shall be regarded with suspicion."

No standards are available to suggest thresholds for concentrations of nutrients that cause eutrophication, but the Federal critieria recommend "prevention of any releases that cause enrichment leading to any major change in the natural levels of flora (attached or floating plants, including phytoplankton)."

CARRYING CAPACITY THRESHOLDS

There is not sufficient data for Maryland tide waters with which to establish *prima facie* threshold limits; i.e., measurements which could be used to signal the thresholds of environmental limits to boat activity. For example, it would be most useful if one could say with finality that turbidity must not exceed, say, 40 Jackson Turbidity Units and therefore human acitivity, including boating, should be limited to that which would not cause such stirring of sediments as to exceed this amount. Unfortunately, the basis for establishing such standards does not exist. To provide such a basis would require a special research program to analyze existing data and to prepare threshold values for a number of parameters With it, a team capable of integrating fields of adminstrative law and ecosystems analysis should be able to provide some answers.

It should be possible to paramatize some ecological conditions and reach verdicts on the limitations of carrying capacity. It might be done for turbidity, eutrophication, flushing of water bodies, and so forth. With such standards it would be simple enough to establish monitoring programs to determine when the nominal carrying capacity of an ecosystem is close to being exceeded, or has been. A further extension of this would be to develop a predictive capability so that one could estimate, beforehand, the probable limits of loading of the ecosystem in terms of boating activity and other existing activities, perhaps through refined turbidity and contamination indices such as the trial ones we have suggested.

INDICATOR SPECIES

A recent intensive investigation of the biota of Chesapeake Bay failed to provide any simple biotic tests of environmental conditions ("Biota of the Chesapeake Bay", Chesapeake Science, Vol. 13 Suppl., Dec, 1972): "simple, unequivocal standards...are not available." Those that have been used "can be interpreted only by comparative study and experienced judgement." The idea is that trained scientists who have the opportunity to study and measure a variety of species are able to make a judgement of biotic condition but they can provide no single bellweather species, or set of species, which can be readily inventoried to provide valid diagnoses.

We believe a more promising approach is the measurement of physical or chemical conditions of the environment, as previously mentioned, or perhaps the presence and condition of aquatic plants. For example, the following associations between specific plants and environmental conditions should provide useful indications (adapted from "Biota of the Chesapeake Bay"):

Plant	Condition
Widgeon grass (<u>ruppia maritima</u>)	Presence may indicate that turbidity conditions are acceptable.
Sealettuce (<u>Ulva</u>)	Dense concentrations may indicate eutrophication caused by sewage, etc.
Watermilfoil (<u>Myriophyllum spicatum</u>)	In fresher waters, presence is adverse (may indicate eutrophication).
Wild celery (<u>Vallisneria</u>) or pond weed (<u>Potamogeton</u>)	Presence may indicate good conditions.
Eel grass (<u>Zostera maritima</u>)	In saltier waters, presence may indicate good conditions.

INTERIM MEASURES

Until such time as a program of threshold monitoring is developed it is suggested that planning effort be given to diversion of boating facilities and surface activity away from areas of high ecological sensitivity. The following aspects are of particular relevance:

1) Insofar as water quality is concerned, the most critical factor is volume of the water body. Small bodies can take much less contaminant than larger ones. For example, dissolved copper (from bottom paints) could reach damaging levels in confined basins.

2) Flushing rate is interactive with water body volume; the higher the rate, the faster the system cleanses itself and the higher is the capacity to absorb contaminants.

3) Both the thickness and the fineness of bottom sediments are important. A water body that has accumulated a thick layer of very fine, and easily suspended, particles is easily contaminated by propwash from passing surface traffic.

4) The ecological characteristics of the shore are important too in relation to facility plans which require shore alteration. For example, any installation of marina or landing ramp facilities in marshes should be viewed with concern. The marshes play an exceptionally valuable ecological role, as previously described.

5) The characteristics of submerged areas are also an important consideration. For example, marine grasses play an important ecological role and boating activity that would seriously reduce their extent should be viewed critically.

6) Any plan to accommodate boating that requires channel dredging should be viewed seriously. Dredging can be ecologically destructive if not properly planned. It can eliminate vegetation, cloud the water with turbidity, over-fertilize the water, cover marshes with spoil, and erode the shore (see figure below).

Biological Effects of Motorized Boating on the Tidal Marsh Estuarine Ecosystem

William A. Niering*

ABSTRACT

The tidal marsh-estuarine ecosystem comprises a complex set of ecological communities sensitive to impacts generated by excessive motor boat traffic. The impact of prop wake, wash and cutting can result in significant physical disturbance to intertidal and benthic communities. Oil pollution poses another major and continuing threat to marine organisms, certain of which are extremely sensitive to hydrocarbon residues. Through biological magnification in estuarine food chains the presence of carcinogenic substances also poses a potential health hazard to man. Carrying capacity for motorized craft must be kept below that which results in tainting of fish. However, further research is needed to determine ecologically safe levels in order to maintain the biological integrity of the marine systems involved.

THE BIOLOGICAL RESOURCE

The Chesapeake Bay marsh-estuarine system is one of the most extensive and productive along the Atlantic Seaboard (Cronin & Mansueti 1971; Lippson 1973). This land-water interface is recognized as an invaluable shellfish and finfish resource for both commercial and private recreational pursuits (Niering 1967). In addition to its marine productivity, it provides many other recreational benefits to the thousands who live near this liquid asset. Motorized boating is one of these activities whose impact has yet to be fully evaluated and recognized by the general public.

The biological system subjected to this technological impact includes the brackish estuarine waters which range from 20-30 o/oo (parts per thousand) at the mouth of the Bay to 3-8 o/oo northward. Within this gradient there occurs a diversity of estuarine communities. The estuarine phase includes the benthic (bottom) community and the open water (pelagic) component overlying the bottom sediments. Here a diversity of populations including phytoplankton, amphipods, copepods, annelids, shellfish and finfish represent the important and highly productive component of this system.

The marshes represent a contiguous interrelated component of this biological system. The most saline occur near the mouth of the Bay where salt marshes are characteristic. Here the salt water cordgrass *Spartina alterniflora* dominates the intertidal zone. On the high marsh the salt meadow cordgrass *Spartina patens* is most important. Within this pattern occurs a diversity of other species tolerant of saline conditions. Locally, forbs such as sea lavender (*Limonium carolinianum*) and arrow grass (*Triglochin*

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maritima) may be present. Slight changes in the micro-relief of the peat surface can also result in floristic changes which favor spike grass (*Distichlis spicata*) and rushes (*Juncus gerardi* and *J. roemerianus*). Thus a mosaic of vegetation occurs along the major channels and the myriad minor tidal creeks that form a network within the wetlands.

As one proceeds up the estuary the increasing amount of fresh water favors brackish estuarine and fresh estuarine bay marshes where narrowleaf cattails (*Typha angustifolia*) and bulrushes (*Scirpus* spp.) now become the dominant phase with the salt water cord grasses restricted to the creek margins. With increased freshness the typical floating and emergent plants of fresh water marshes may appear. The overall pattern is for the more saline species to occur nearer the edges of the open Bay and the fresh water forms to predominate farther up the major channels and creeks. Associated animal populations on the marsh include the crustaceans (amphipods and crabs), mollusks and snails. With this biological setting of the resource we shall now turn to the sources of pollution and their potential impacts.

SOURCES OF POLLUTION AND POTENTIAL IMPACTS

The use of motorized craft can result in two major impacts--physical and biological--in terms of modifying the site conditions of the community and in affecting the populations of organisms within the estuarine environment. These impacts and subsequent interactions on this biological system are shown in Table 1.

PHYSICAL FACTORS

Motor boats create a wake that transmits energy in the form of waves. These may be dissipated in open water with minor effects. However, in narrow tidal creeks their impact may impose a severe stress on the intertidal marsh community that has not naturally evolved under these conditions. In the bay front salt marsh intertidal salt water cordgrass zone where severe tidal and wave action is often characteristic, a dense root mat has developed along with a dense ribbed mussel population (*Modiolus demissus*) which helps to bind this peaty substrate. With excessive erosion this protective intertidal biotic association can be destroyed, opening the site to continued erosion. The fine sediments eroded are now carried and deposited elsewhere and in the process increased turbidity of the water results. Depending upon the degree of turbidity caused by the suspension of fine organic, silt and clay particles, light penetration is lower which in turn lowers photosynthetic rates of the phytoplankton. Since phytoplankton forms the base of the marine food chain this decreases the productivity of the estuarine system. It should be noted that 500 lbs. of phytoplankton from the estuary can have contributed directly through the marine food chain (phytoplankton--zooplankton--copepods--small fish--larger fish--tuna) to the production of 1.5 ounces of tuna. Speed boating in narrow creeks 10-15 feet wide or less may initiate such erosion. In Connecticut there is considerable evidence that intertidal erosion can occur in much wider areas where waterskiing is continually practiced (Niering and Warren 1974). Increased intertidal erosion can also result in loss of grass productivity and favor the increase of less productive grasses and forbs.

Increased turbidity is also caused by prop wash which in shallow creeks and channels seriously disrupts the bottom sediment dwellers. Amphipods, annelids, crabs and shellfish are all intricately adjusted to some sediment transport in the normal erosive processes and during periodic storms. However, constant disturbance of the bottom sediments can interfere with the filter feeding organisms characteristic of this environment. Actual smothering of bivalves can occur with increased sediment disturbance as has been documented in dredging operations.

Motor boats may also cut off or churn up submerged vegetation such as Ruppia and eel grass in shallow estuarine waters. This material is then washed up on the marsh and kills the marsh grasses or accumulates in the bottom sediments at such a rate as to favor anaerobic rather than aerobic respiration. The former is usually a pollution indicator and lowers species diversity (Rhoads and Young 1970).

Boating activities also necessitate the construction of marinas and the periodic dredging of channels. Both of these activities can be and have been degrading to this environment by smothering shellfish beds and filling productive tidal marshes with the spoil from channel dredging, as well as the filling and dredging of marshland in marina construction. Spoil disposal in other aquatic areas may also be detrimental to benthic forms.

CHEMICAL-PHYSICAL FACTORS

Another major environmental impact of motorized boating is water pollution resulting from the outboard fuel. It is estimated that 10-33 percent of the fuel is discharged into the cooling water exhaust stream as unburned waste products (Stewart & Howard 1968). Data taken at Lake George, New York, where boating pressure is increasing rapidly predict that if the rate of fuel usage continues, the lake water could have a semi-permanent fuel odor within eight years (Stewart and Howard 1968).

When oil and water are combined, fine droplets are formed that can be highly dispersed in the water column. When these droplets come in contact with a surface less polar than water, such as organic sediments, sand and silt or other debris, they are strongly bound to these materials. Therefore, oil can coat the bottom sediments of a lake or estuary. It should be noted that oil does not harmlessly disappear or evaporate, but becomes part of the underlying sediments (D.E. Harrison, mimeo report). Although bacterial degradation of oil may occur it is not a rapid process. For example, bacterial action may not begin until more than eight months after an oil spill and once initiated the least toxic straight chain hydrocarbons are degraded first and the more toxic aromatics remain in the sediments (Blumer et al 1971). Experiments conducted in fresh water can taint sunfish and other species (English et al 1963a, 1963b). Data from even very minor oil spills have documented the loss of algae (seaweeds) and higher vascular vegetation such as the marsh grasses. Marine invertebrates can also be greatly reduced or eliminated. The crustacea, especially amphipods, are particularly sensitive to oil pollution (Sanders et al 1972).

Although it may be argued that the relatively low level pollution from motor boats cannot be equated with major oil spills, it should be realized that

OIL POLLUTION AND BOATING IN RELATION TO CARRYING CAPACITY

Boating must be considered a significant source of oil pollution in the marine environment, especially since it is a continuously occurring activity during certain seasons. In well flushed bay fronts the dilution or removal of the oil, regardless of its source, is constantly occurring. However, in the more quiescent waters of the small tidal creeks and shallow embayments where motorized traffic is heavy, one can expect higher levels of oil pollution which have an adverse effect upon the benthic and open water animal populations. Areas that are poorly flushed by the tides will tend to concentrate petroleum products which are in turn concentrated at the various trophic levels in the food chain. It would appear that although motorized craft present no dramatic pollution problem such as a major oil spill, their concentrated traffic within a limited area adds a continuous source of oil pollution to coastal waters that are already under severe stress in most coastal environments (Niering 1970; Ketchum 1972). There is a limited carrying capacity for motorized craft. The level will vary within every aquatic system depending upon the current environmental stresses and the physical and biological conditions of the system. The following recommendations may provide some guidelines in formulating carrying capacity limits.

RECOMMENDATIONS

1. Although the Environmental Protection Agency has been undertaking research on the biological effects of motor boats in aquatic systems, much more data must be derived, especially as related to marine systems. Based on the data available, every effort should be made to minimize boat traffic in the most vulnerable habitats. Speed boating and waterskiing should be eliminated from narrow shallow creek channels where bottom sediments will be disturbed and the marginal intertidal vegetation subjected to erosive stress.

2. Oil pollution should be constantly monitored in the waters and sediments of estuarine areas where heavy boat traffic occurs. When the source of the oil can be traced to motorized craft a decrease in carrying capacity would be in order. Oil levels should be kept well below those levels which result in tainting of finfish or shellfish flesh. This occurs at a fuel usage of eight gallons of outboard motor fuel per million gallons of lake water. Obviously this formula becomes more complex in the estuarine environment where tidal dilution occurs. Further research in this area is urgently needed.

3. In the context of the potential carcinogenic effects of petroleum products and the energy crisis, which will only intensify in magnitude in the future, a public effort should begin to promote the increased use of wind powered craft rather than motorized boats. Although it is realized that there will be a period of transition, to delay initiation of such a step will only prolong the transition.

4. Increased public awareness through various media is needed to alert marina and boat owners to the potential environmental hazards of this "recreational" activity.

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Table 1

Physical Factors	Effects			
Boat wake	Erosion	Loss of intertidal vegetation	Accelerated erosion, loss of productivity	
Prop wash	Turbulence	Increased turbidity	Decreased light penetration and increased siltation	Lowered phytoplankton productivity and smothering of shellfish beds
Prop cutting	Destruction of eel grass and Ruppia in shallow water	Loss of productivity and waterfowl food	Increased eutrophication	
Dredging & filling	Loss of productive marsh or mud flats	Increased turbidity	Lowered phytoplankton productivity and smothering of shellfish beds	
Spoil disposal		Increased sites for establishment of Phragmites and lesser desirable estuarine species		

Chemical-Physical Factors	Effects		
Release of hydrocarbon residues	Introduction of diversity of petroleum residues	Subtle decrease in population levels Behavior changes Loss of estuarine populations Carcinogenic effects (PAH)	Potential human health hazard
Release of sewage wastes	Nutrient enrichment	Increased marsh productivity Increased eutrophication	Switch from aerobic to anaerobic system
Exhaust fumes	Increased air pollution	Potential health hazard	

low level chronic spills may be equally as dangerous to the stability of steady state marine systems as massive concentrations. The effects of low levels may be so subtle as to almost defy detection and yet food chains or webs may be modified. This rationale was used in the case of banning DDT where marine phytoplankton productivity was reduced by very low concentrations of this insecticide. It is well known thatlower chain organisms such as the amphipods common in the estuarine system are especially sensitive and excellent indicators of oil pollution. Subtle low level reductions in populations are often extremely difficult to detect, especially in the absence of base line studies for comparative purposes. All data suggest that oil is toxic to many marine forms or can modify their physiology even if mortality is not a major factor. For example, in the West Falmouth oil spill considerable areas of S. alterniflora were killed and the fiddler crabs characteristic of this habitat were greatly reduced. In addition, behavioral effects were also detected. The animals were readily observable during the daylight hours and failed to seek cover upon the approach of man. This behavior modification would greatly increase their vulnerability to predation.

Hydrocarbon pollution can also result from small oil spills at marinas or by the boat owners themselves. This adds one further source of pollution.

The release of sewage from boats into estuaries is a source of nutrient enrichment. Although regulations are tending to discourage this practice, enforcement will not be easy. Human sewage may increase tidal marsh productivity, but it also increases the coliform count and eutrophication of adjacent marine waters to the point of altering the floristic and faunistic composition and closing the area to the taking of shellfish. Extremely excessive amounts can tilt the balance from aerobic to anaerobic conditions where species diversity declines, especially those species beneficial to man.

Exhaust fumes add to the air pollution levels in coastal regions where concentrations of people and industry are frequently already stressing the environment.

However, an even more subtle effect of oil is its carcinogenic effect on humans (D.E. Harrison, mimeo report). Heuper (1957) has suggested that environmental factors (as well as better diagnoses) may be responsible for the large increase in leukemia in the United States. As early as 1910 petroleum oil fractions were found to cause skin cancer. Although only a small group of people exposed to environmental cancer inducers develop the disease, decades of elapsed time may occur between the stimuli and tumor development. Petroleum carcinogens, although water insoluble, are soluble in non polar lipids of living organisms. They can also be biologically magnified in the food chain. Within petroleum the benzine and 3.4 benzopyrene fractions, a polycyclic aromatic hydrocarbon (PAH), are the most important carcinogens.(Arcos and Argus, 1968).

Oil pollution, with boating as one source, an introduce large amounts of PAH into the marine system. Plant roots can also take up benzopyrene from the substrate (Doerr 1965). This same plant material will eventually contribute to the detrital food chain of the estuary upon bacterial decay. That fraction of the carcinogen that will pass on in the food chain is unknown. Tainted finfish and shellfish may contain carcinogens and post a potentially serious health hazard to man. Since PAH is not volatile, even the taste test may not indicate the presence of carcinogens in dangerous amounts.

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APPENDIX C

MAPS: ENVIRONMENTAL CONSTRAINTS

The environmental constraints on boating activities which were identified in Chapter IV have been mapped for application in the Boating Capacity Planning System. The base maps were reproduced with permission from the Maryland Geological Survey at a scale of 1:62,500. The following factors have been mapped:

1) Water Body Types: Sub-Bay Units and Management Units

   Sources: State of Maryland, Water Resources Adminstration, Watershed Designations.

2) Heads of Tide

   Sources: Established by Law, Article 66c and 96A, Annotated Code of Maryland (1957 Edition) and by regulation of the Maryland Department of Water Resources.

3) Marinas: Public and Private

   Source: Maryland Department of State Planning, Maryland Automated Geographic Information System. Baltimore: May, 1974.

4) Public Landings

   Source: Department of Natural Resources, Program Planning and Evaluation. Problems Associated with Public Landings, A Report to the Maryland Assembly in Response to Joint Resolution No. 14 of the 1972 Session.

5) High Shoreline Erosion: Greater than 0.2 acres/mile/year

   Source: U.S. Army Corps of Engineers, Chesapeake Bay Existing Conditions Report, Appendix D Map Folio

6) Clams: Hard and Soft Shell

   Source: Boating Almanac Co., Boating Almanac, 1974 The Chesapeake Bay and North Carolina, Vol 4. 1974.

7) Oyster Beds

Source: Maryland Department of State Planning, Maryland Automated Geographical Information System. Baltimore, May, 1974.

8) Selected Fish Spawning: White Perch, Striped Bass

Source: Lippson, Alice J. (Ed.) TheCChesapeake Bay in Maryland, An Atlas of Natural Resources
Baltimore: Johns Hopkins University Press, 1973.

9) Non-Forested Wetlands

Source: Maryland Department of State Planning, Maryland Automated Geographical Information System, Baltimore; May 1974.

10) Rooted Aquatic Plants

Source: Lippson, Alice J. (Ed.) The Chesapeake Bay in Maryland. An Atlas of Natural Resources
Baltimore: Johns Hopkins University Press, 1973.

Note: Flushing Rates could not be mapped due to the unavailability of accurate and updated information.